NANOPLASMONICS FOR LASER ASSISTED NUCLEAR FUSION

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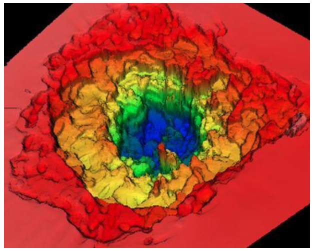
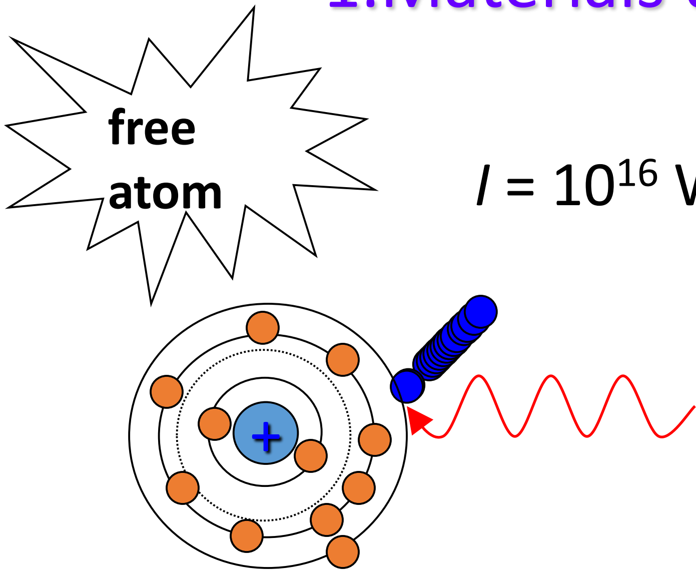
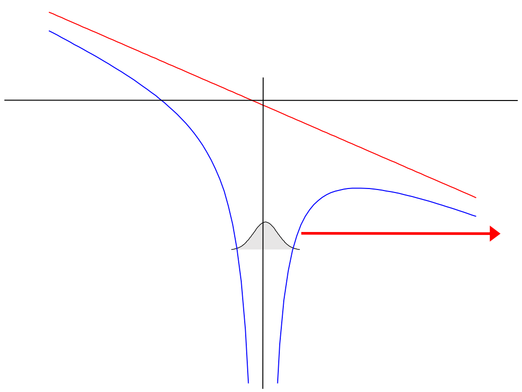
OAK: 03.09.2024



1.Materials under extreme conditions

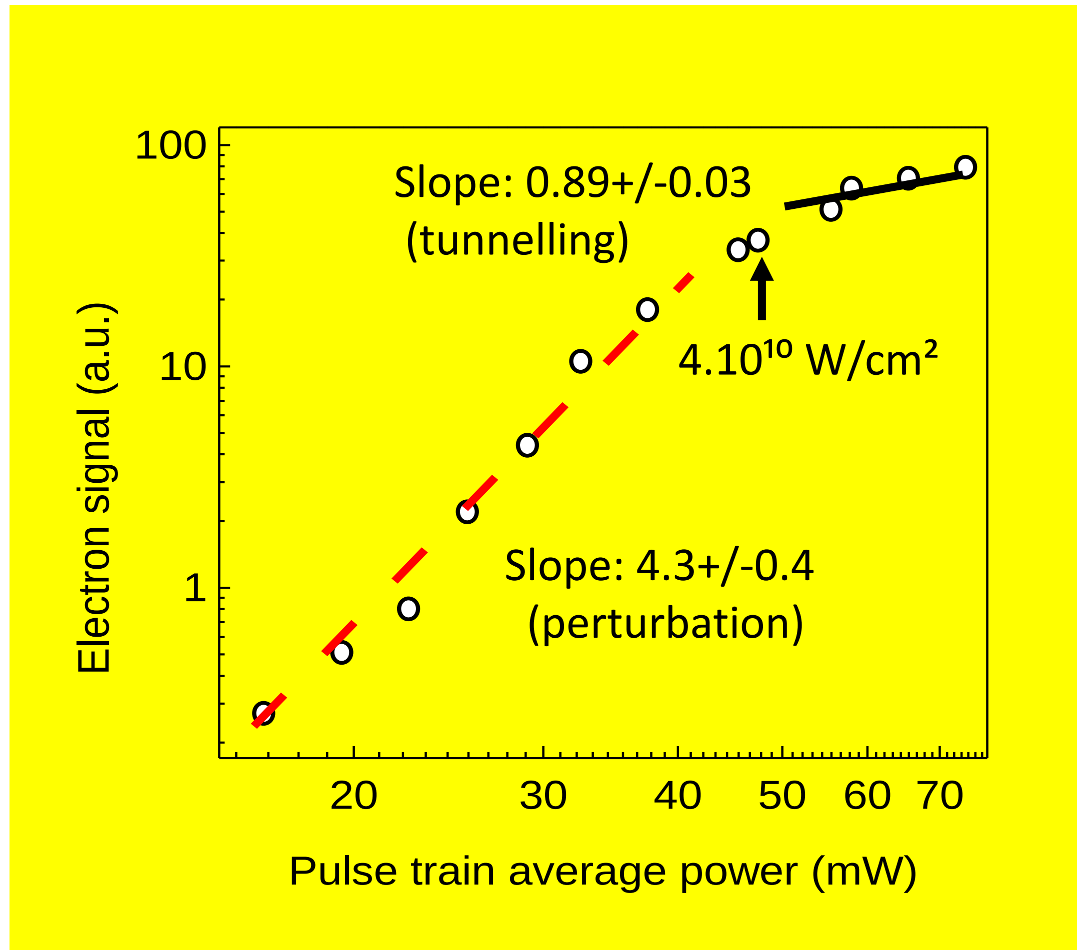


I = 10^{16} W cm^{-2}



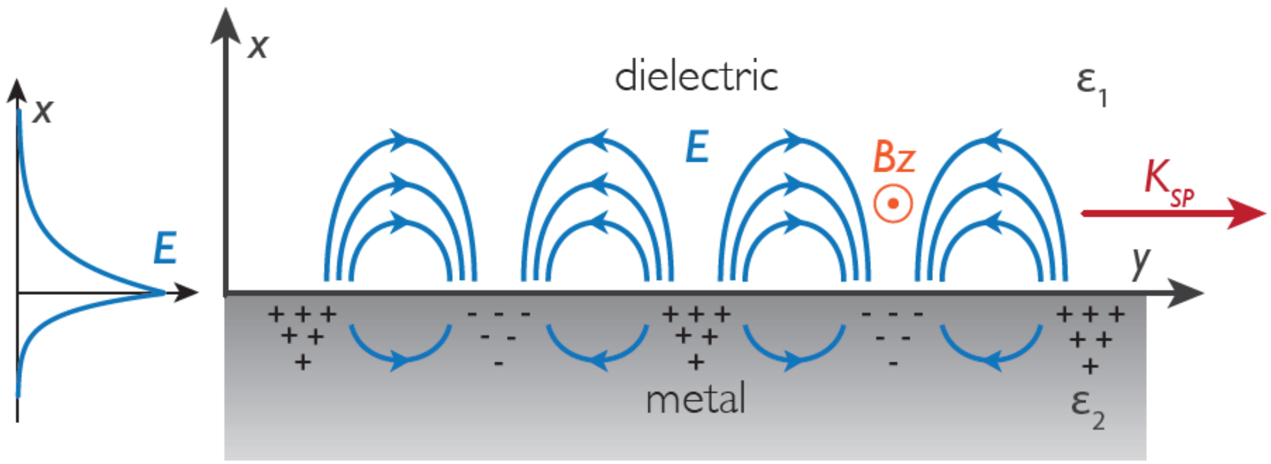
Tunnelling

10^{14} - 10^{15} W cm^{-2}

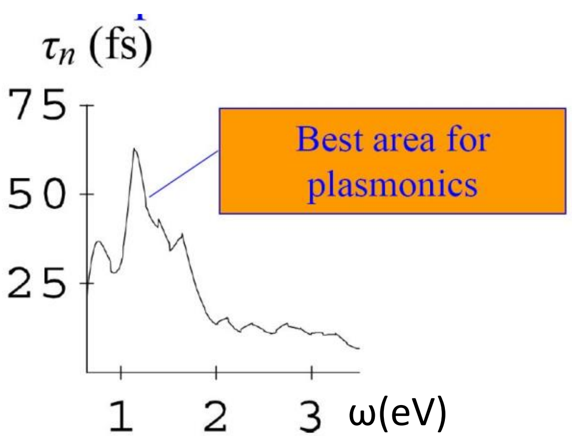


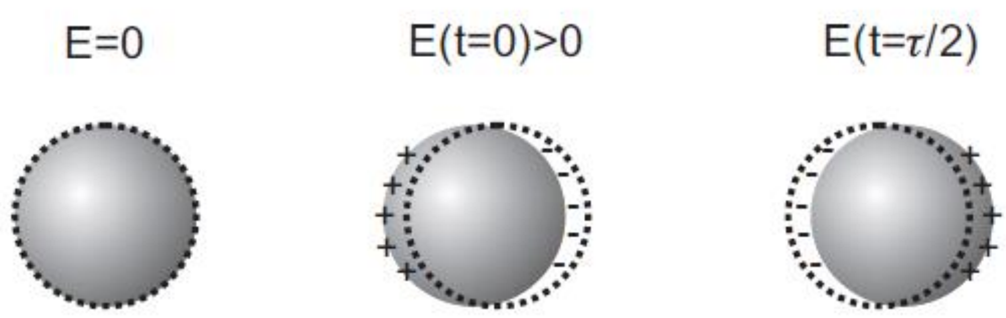
2.PLASMONICS AND HIGH FIELDS APPLICATIONS

Special type of the optical near field



SPP



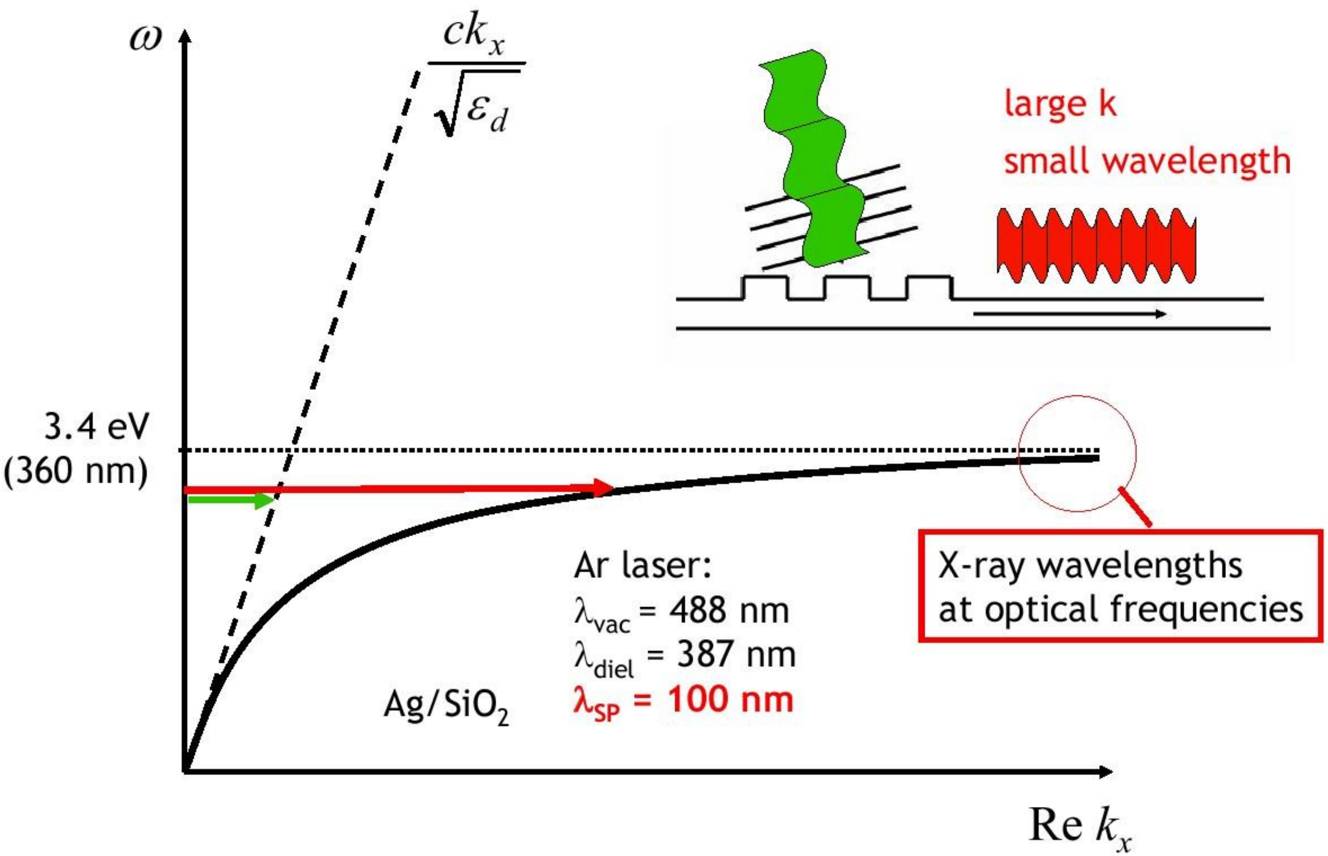


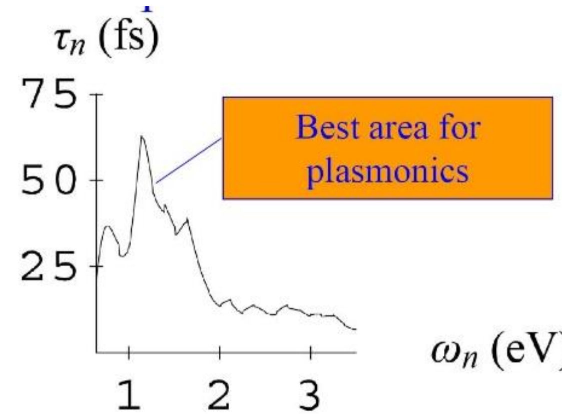
LSPP

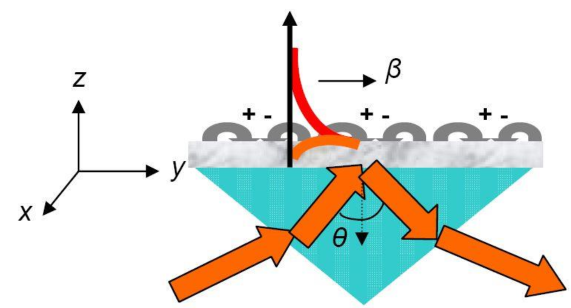
Ti:Sa laser: Λ=800nm (~1.55eV) ; $t_{(SPP)}$~30fs

SURFACE PLASMON POLARITONS (SPP)

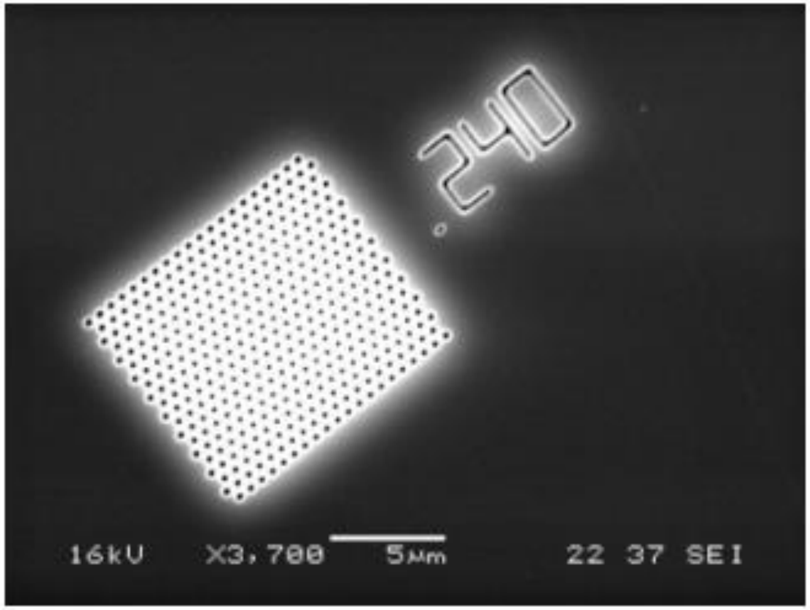
Surface plasmons dispersion: $k_x = \frac{\omega}{c}\left(\frac{\varepsilon_m \varepsilon_d}{\varepsilon_m + \varepsilon_d}\right)^{1/2}$

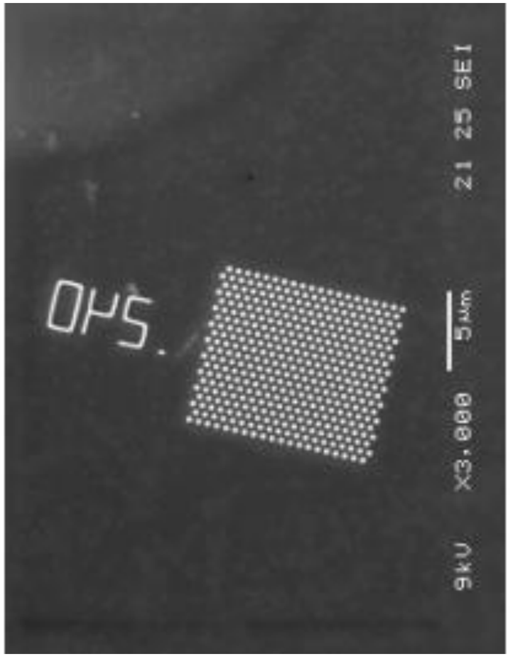


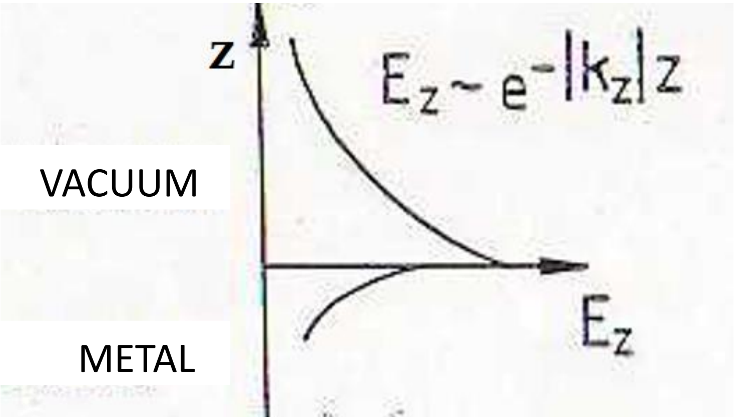




Light gets through holes, much smaller than the wavelength.





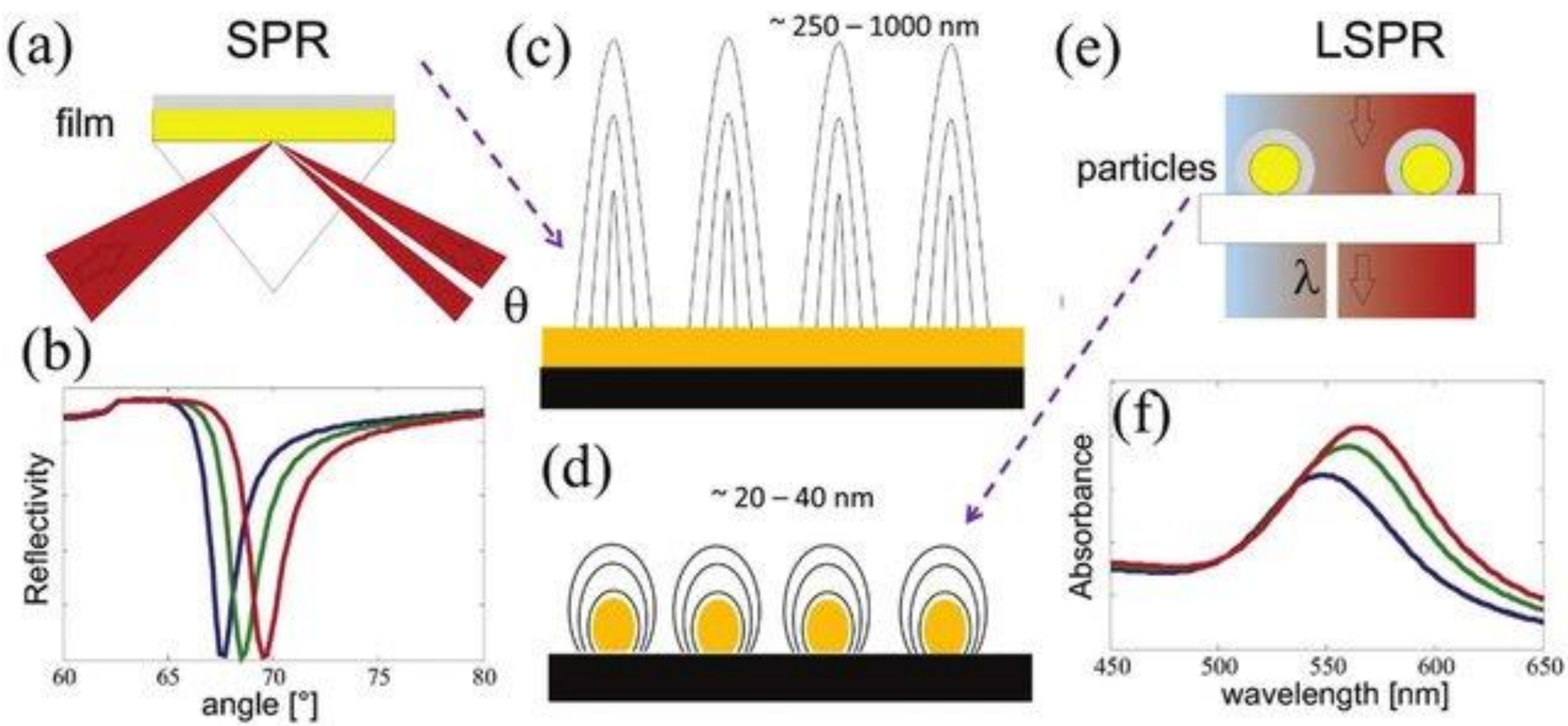


MOST OF THE ENERGY IS CONCENTRATED AT THE SURFACE:
GIANT FIELD AMPLIFICATION

MANY POTENTIAL APPLICATIONS.

2.LOCALIZED PLASMONS (LSPP) UP TO 10^{20} W/cm^2)

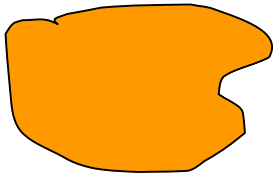
(The basic difference between SPP-s and LSPP-s)



LSPP: -NO PENETRATION INTO THE PLASMONIC MATERIAL (e.g. metal)
- SMALLER PENETRATION INTO THE DIELECTRIC /VACUUM
-NO DISPERSION, RESONANCE DEPENDS ON SIZE, SHAPE, MATERIAL
-BROADER RESONANCE

PLASMON RESONANCE OF NANOPARTICLES SHAPE AND- ÉS SIZE DEPENDENT!

$$\omega_B = \sqrt{\frac{4\pi e^2 n}{m_e}}$$

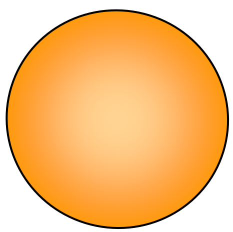


Bulk

$$\omega_{surf} = \frac{\omega_B}{\sqrt{2}}$$

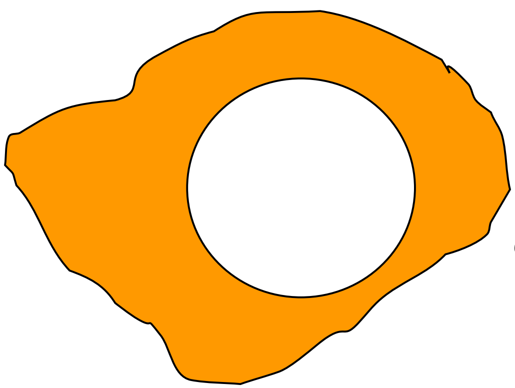
Surface

$$\omega_{S,l} = \omega_B \sqrt{\frac{l}{2l+1}}$$



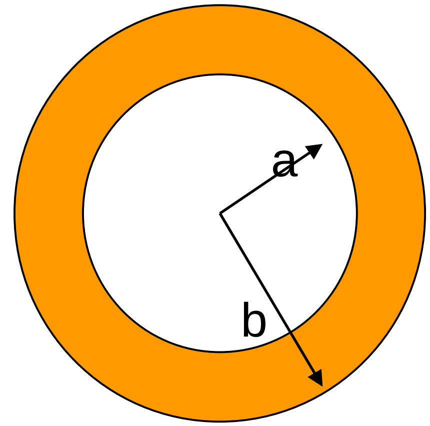
Sphere

Üreg



$$\omega_{C,l} = \omega_B \sqrt{\frac{l+1}{2l+1}}$$

Nanoshell:



$$x = \frac{a}{b}$$

$$\omega_{l\pm}^2 = \frac{\omega_B^2}{2}\left[1 \pm \frac{1}{2l+1}\sqrt{1+4l(l+1)x^{2l+1}}\right]$$

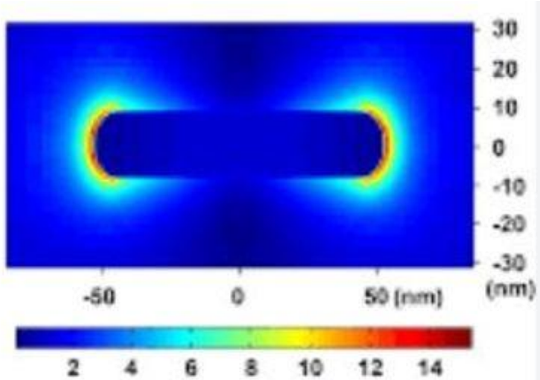
Nanoshell plasmon resonance depends on the x ratio .

-HOT SPOT

-SCREENING

-PONDEROMOTORIC ACCELERATION

-CORRELATED MOTION



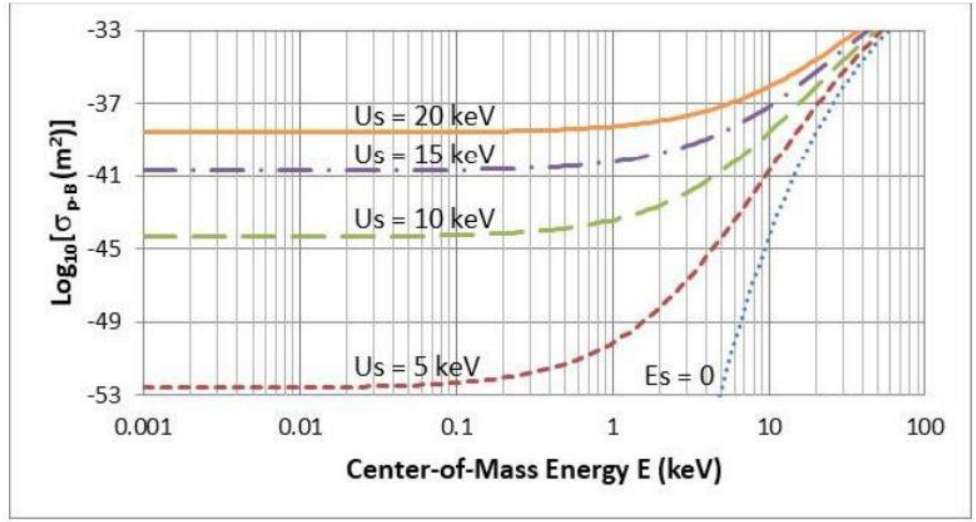
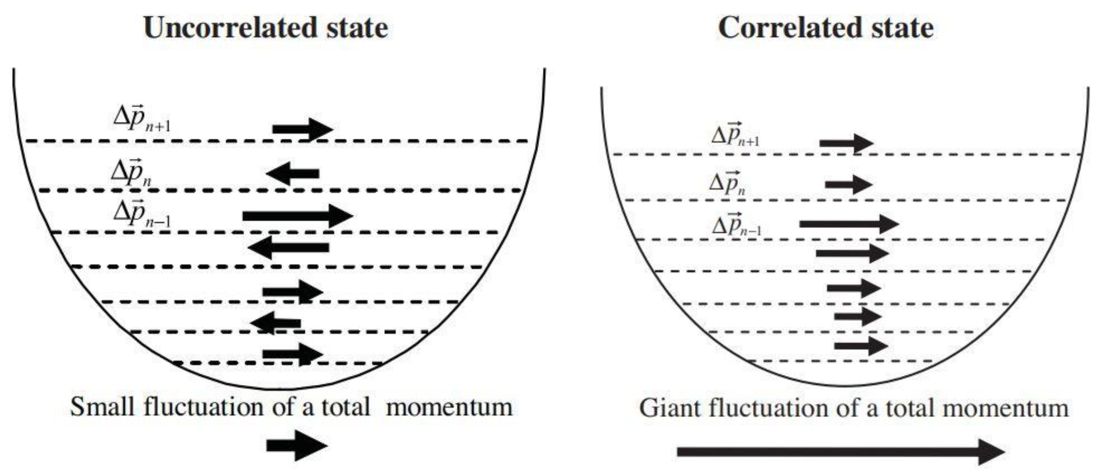
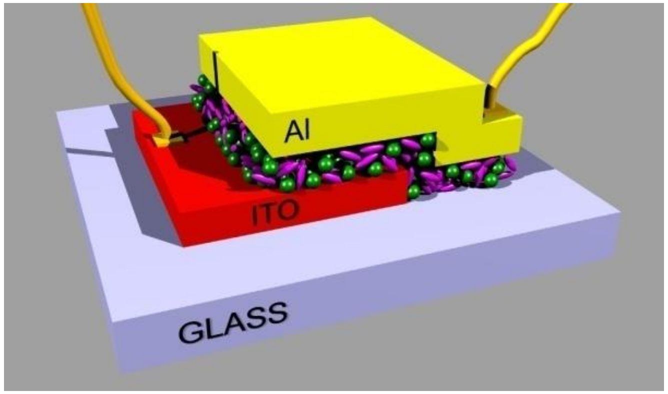


Figure 1: p-[11]B cross section as function of particle energy for the screening electron densities up to E_s = 20keV. The cross section near E = 10eV grows over 14 orders of magnitude (from 10^{-53} to 10^{-39}m^2) over the range of 5 to 20keV.

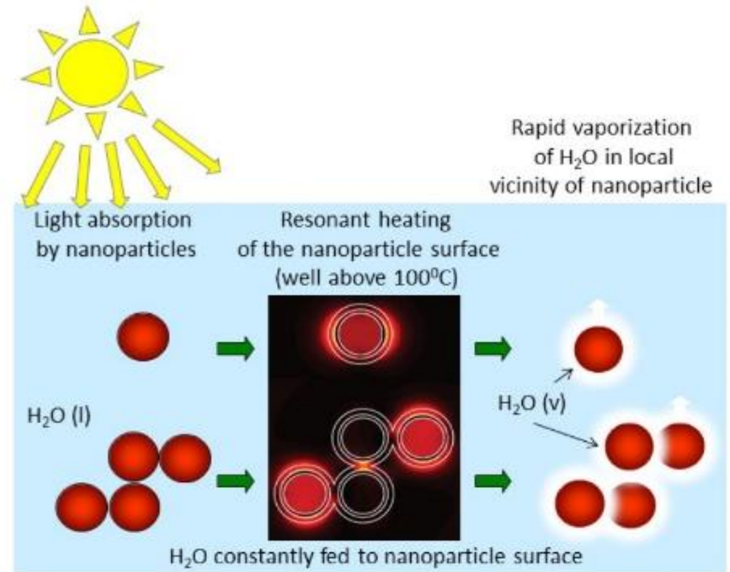


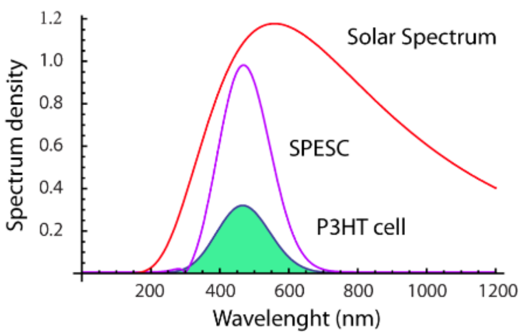
Some potential new energy technologies

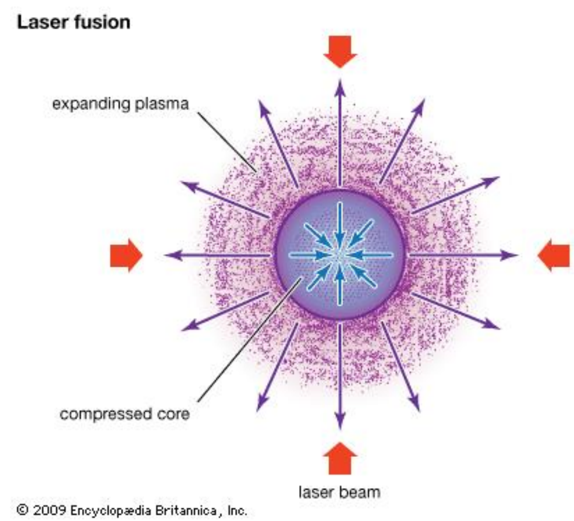
(involving nanotechnologies)

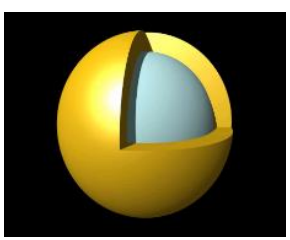


P3HT Cell efficiency = 6%
SPESC (P3HT) efficiency = 17.5%





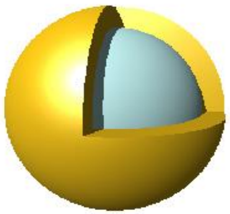




NIF (LASER INDUCED FUSION)

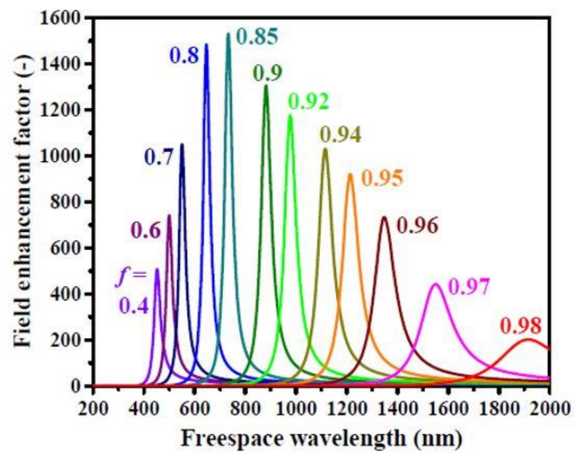
192 laser, 400MJ, on target 2MJ. The generated nuclear energy 3MJ. The cost of one capsule ~10^5USD. The length of the laser pulse : 10-50ns , 1 imp/day. Facility cost: multibillion USD.

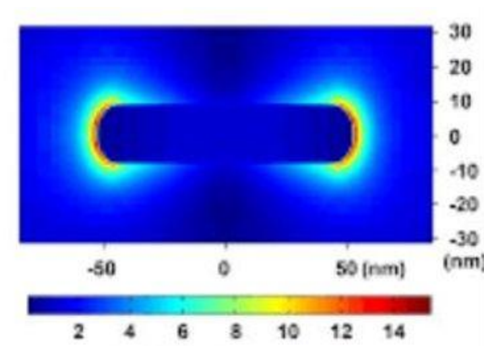
NANOPLASMONICS AND ENERGY CONCENTRATION

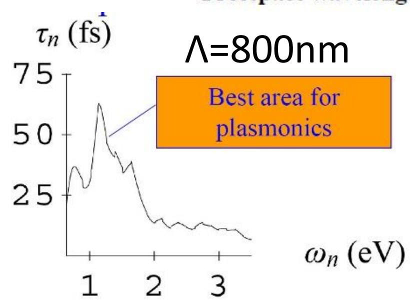


NANOSHELL (nx10nm)

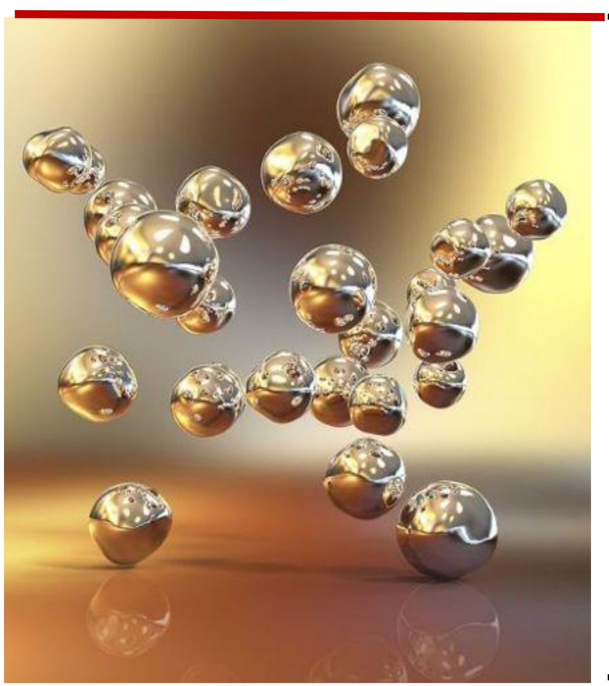
NANOROD (~85x25nm)





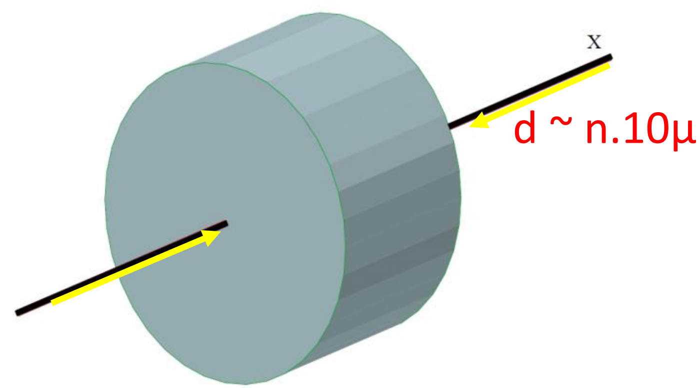


Λ=800nm



n.10μ

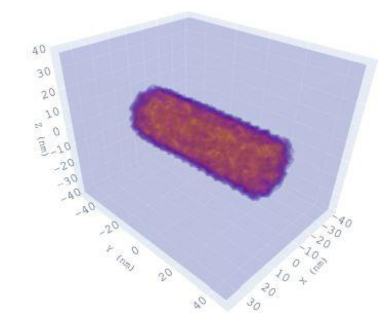
NANOPARTICLES IN THE FUSION MATERIAL

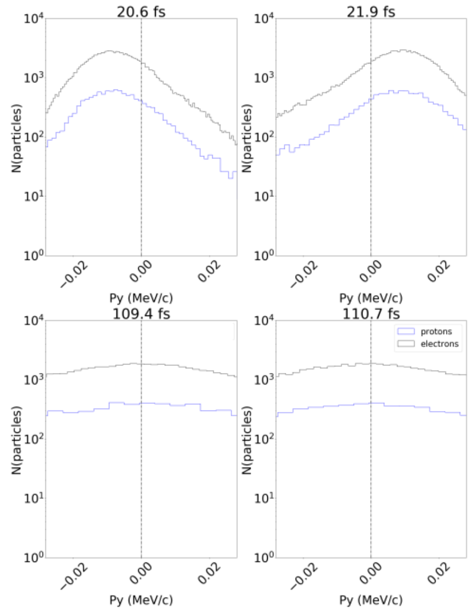


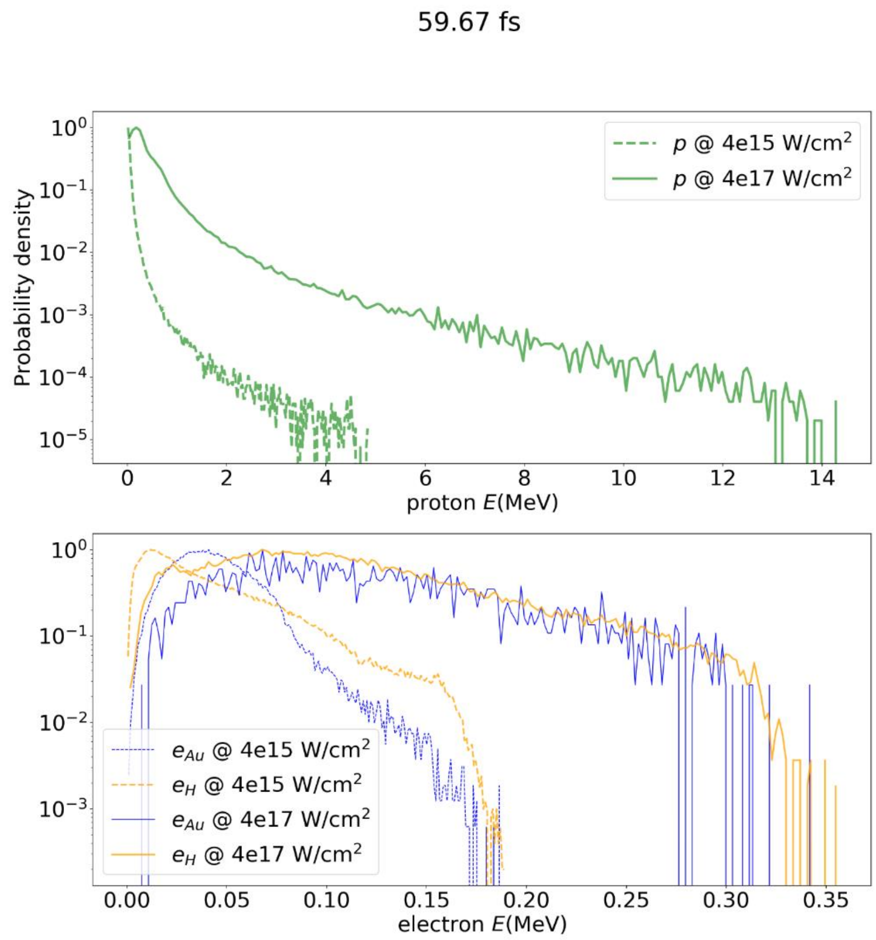
FEMTOSECOND LASER PULSES;
HIGH REPETITION FREQUENCY;
LIGHT SPEED: NO TIME FOR INSTABILITIES; ONLY TWO BEAMS;
TIMELIKE VOLUME IGNITION

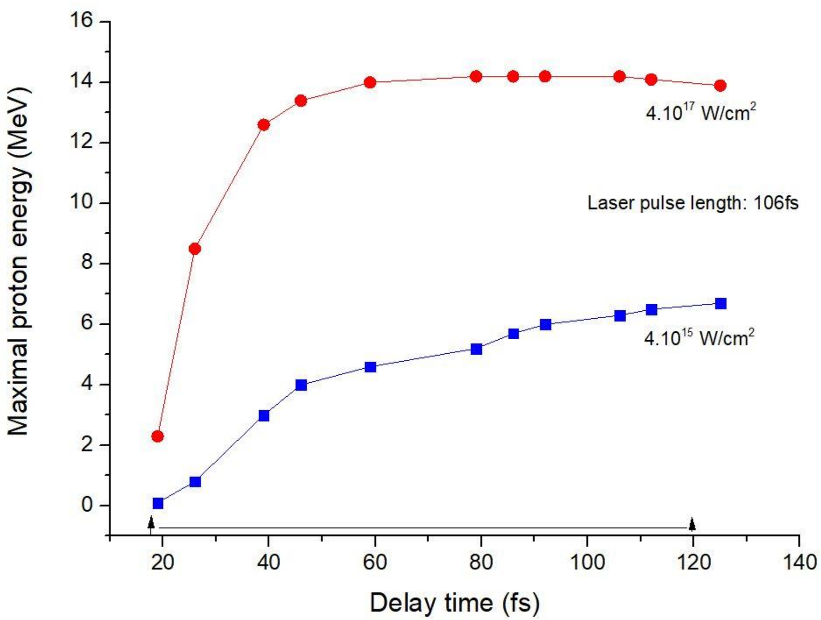
SIMULATION OF PROTON AND ELECTRON ENERGIES AT A SINGLE NANOROD

Nanorod inside a PIC simulation box









AND UP TO ~10^{20} W/cm²

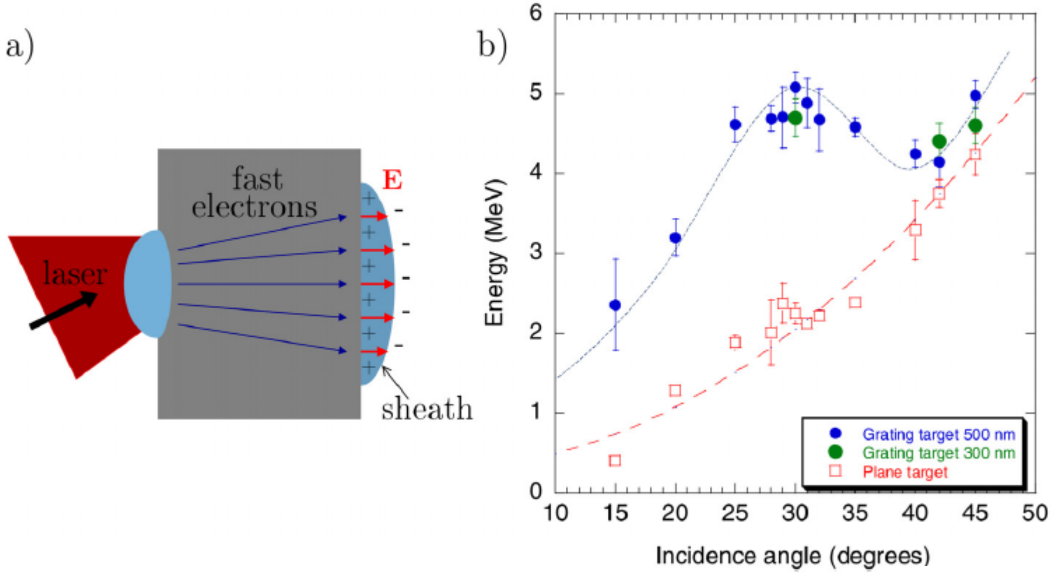


FIG. 5. Plasmon-enhanced TNSA of protons.[95] (a) Schematic of TNSA. The fast electrons produced by the interaction at the front side cross the target and produce a sheath at the rear side, where ions are accelerated. (b) Experimental data from the interactions of a high-contrast 25 fs, 2.5×10^{19} W cm^{-2} laser pulse with solid plastic targets. The cut-off energy of protons emitted from the rear measured as a function of the incidence angle from both flat and grating targets (for two different values of the grating depth). An up to 2.5-fold energy increase is observed for gratings, with a broad maximum around the resonant angle for SP excitation (30°). Data from Ref. 95.

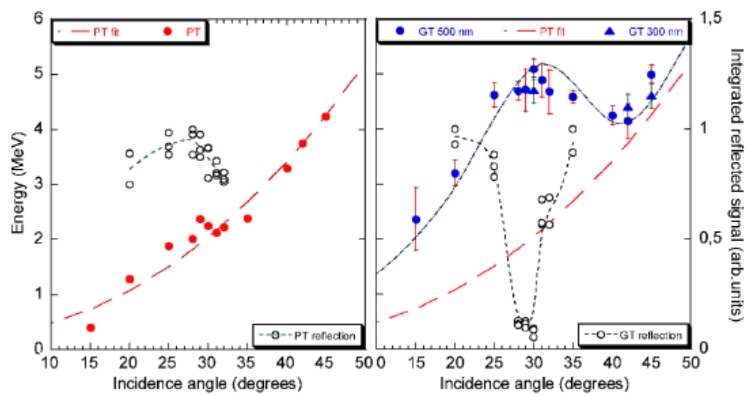


FIG. 3 (color online). Maximum proton energy (filled data points) and reflected light signal (empty data points) as a function of incidence angle α. Left and right frames correspond to 20 μm thick plane targets and to 23 μm thick grating targets, respectively. Filled circles and triangles correspond to 0.5 and 0.3 μm deep gratings, respectively. The (red) dashed line is proportional to $\sin^2\alpha/\cos\alpha$. The other lines are guides for the eye.

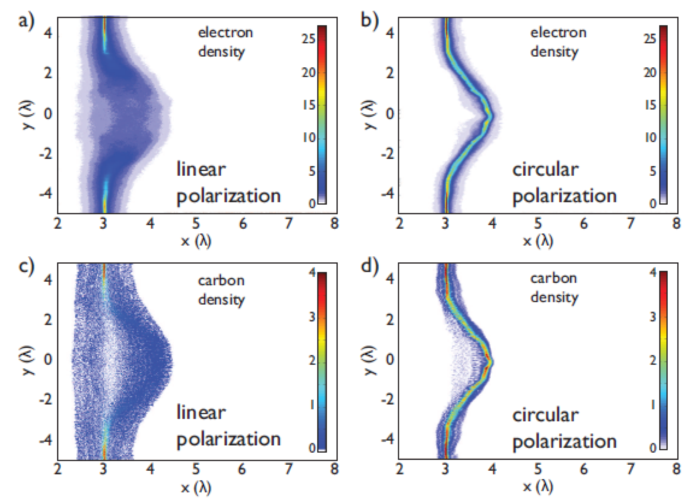
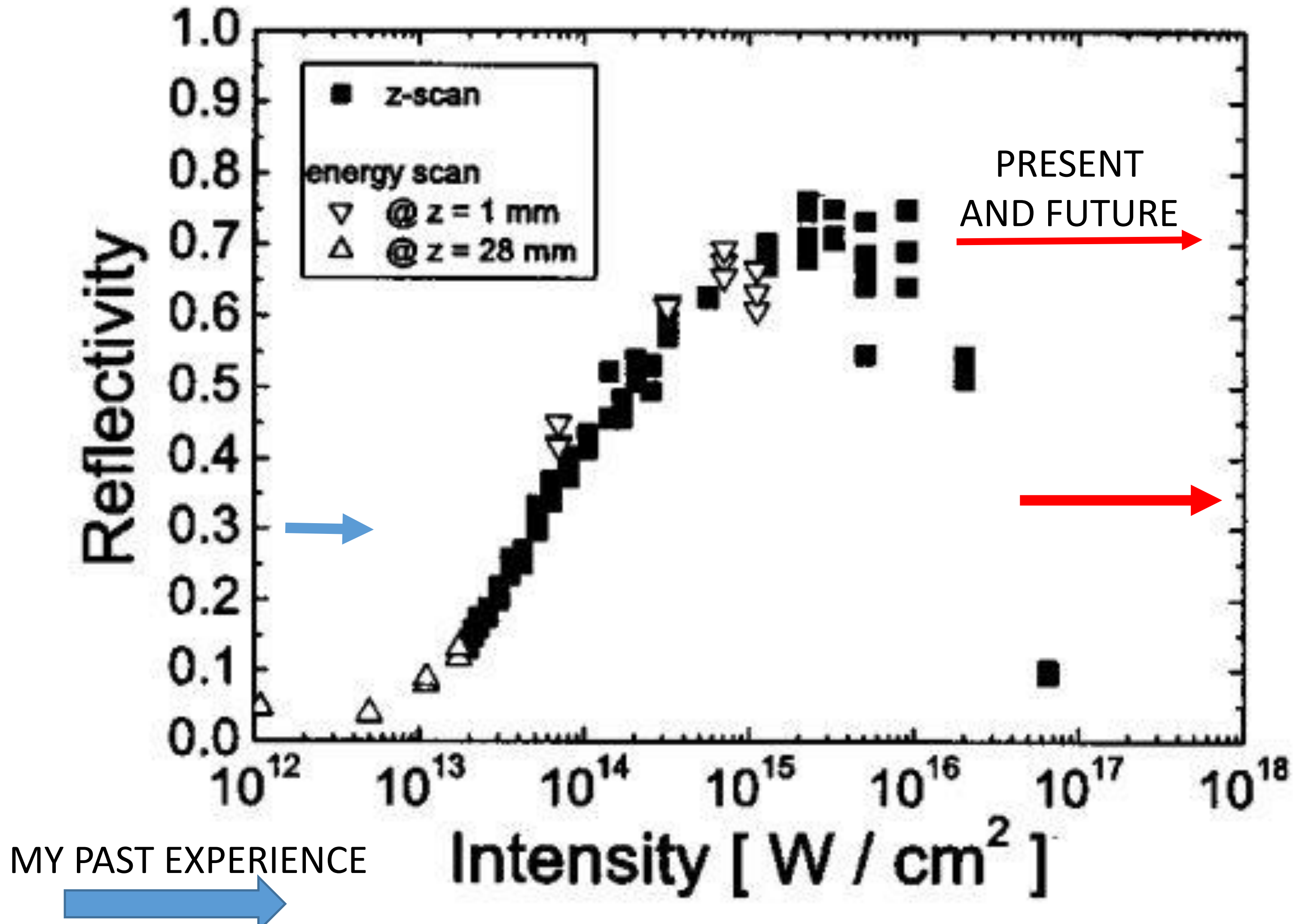
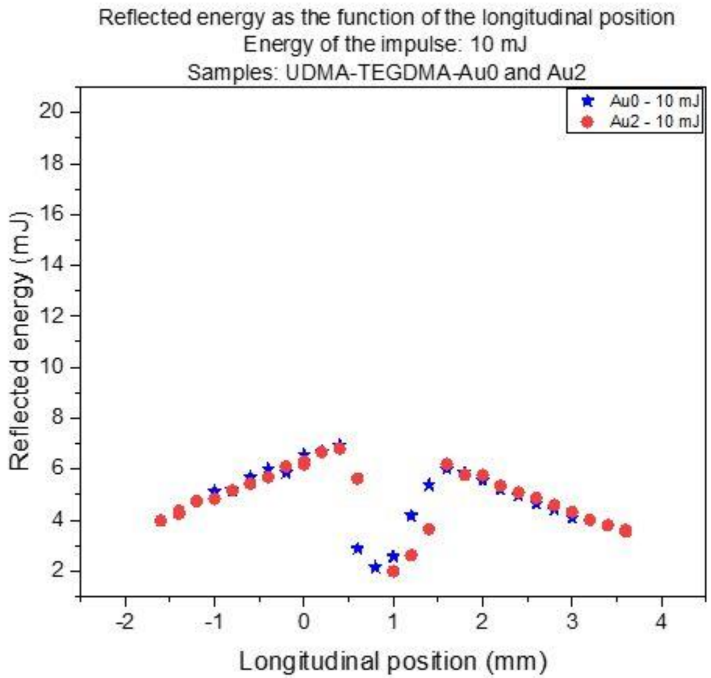


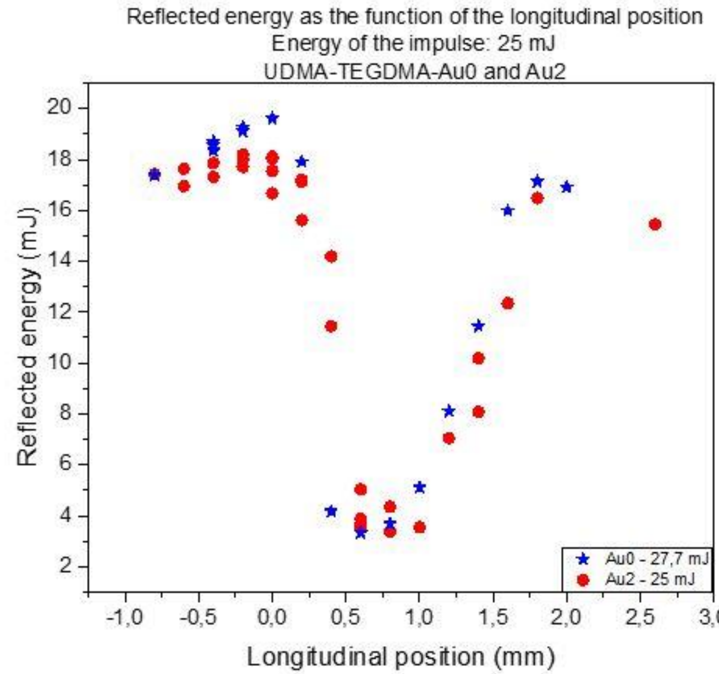
FIG. 4: (color). Cycle-averaged electron (a,b) and carbon ion (c,d) density at $t = 61$ fs after the peak of the laser pulse reached the 5.3 nm target initially located at $x = 3\lambda$. While linear polarization results in strong expansion of the target caused by hot electrons, for circularly polarized irradiation the foil is accelerated as a dense, quasi-neutral plasma bunch.

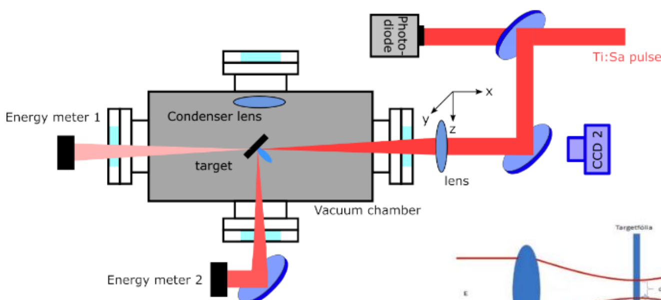
LIGHT-MATTER INTERACTION:
PLASMA-MIRROR REFLECTIVITY
(how can light enter into matter?)

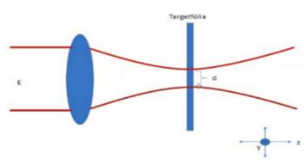


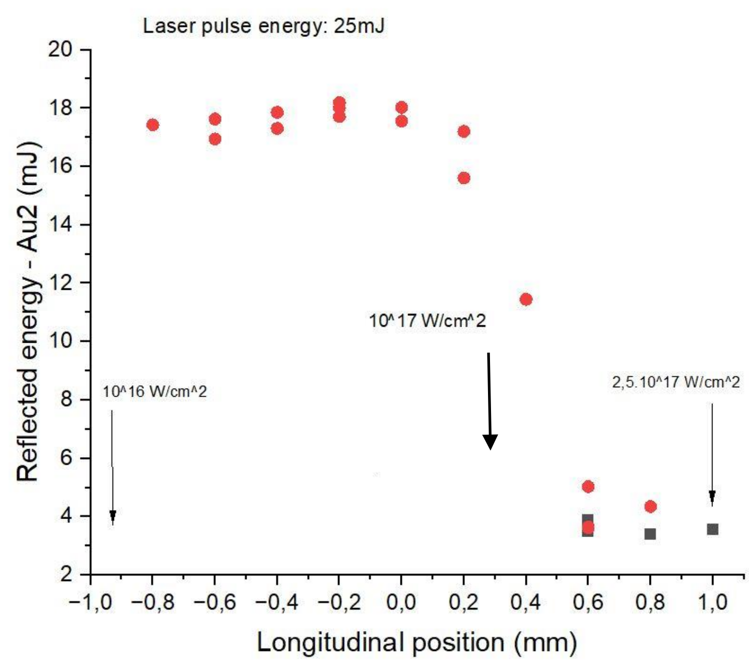
Ch.Ziener at al : J.Appl.Phys. 93,768 (2013)





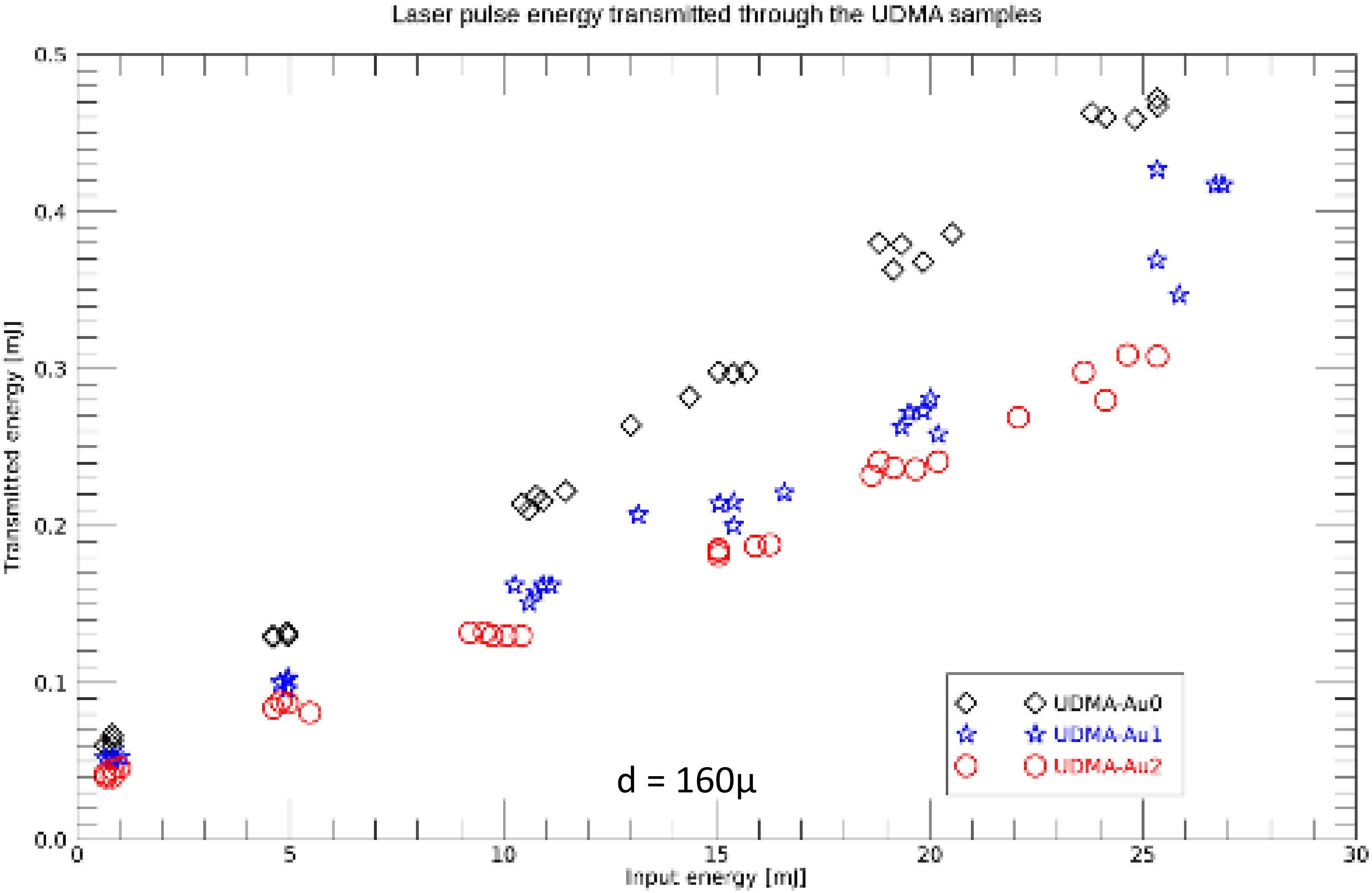






MEASUREMENTS AT WIGNER R.C.

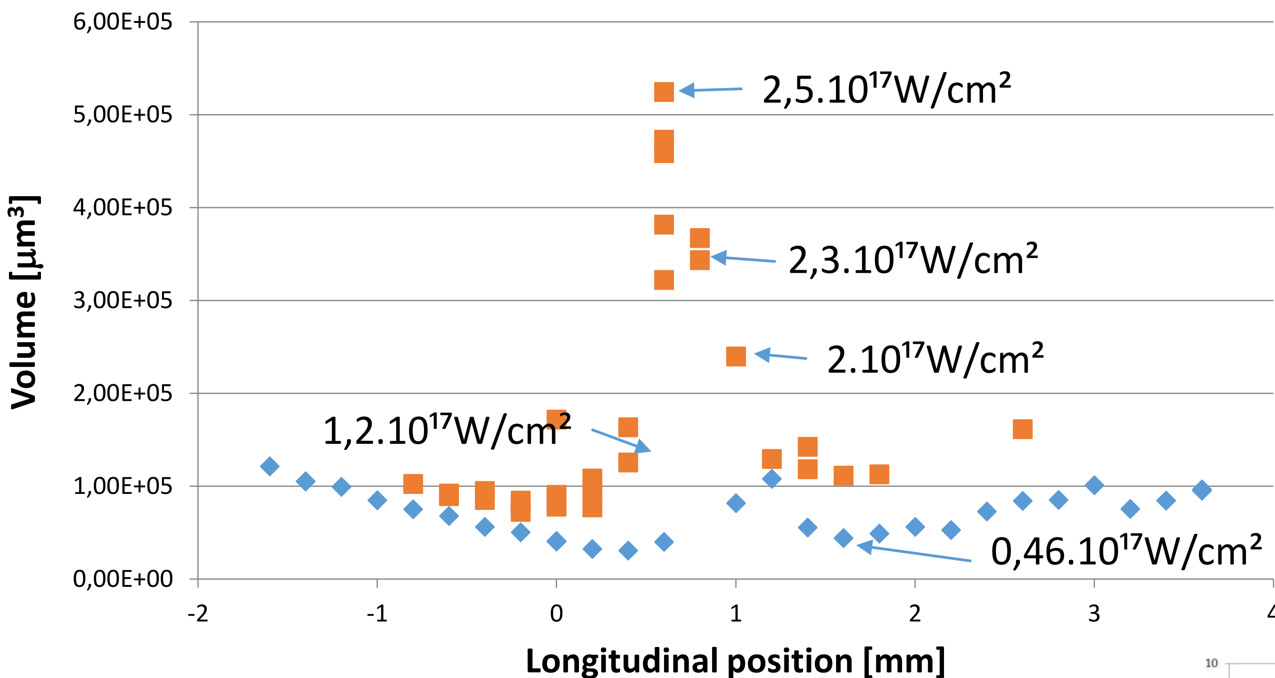
Sample: polymer (UDMA+ TEGDMA) Au2 (0.18m/m%) resonant nanorods and Au0 (without nanorods)

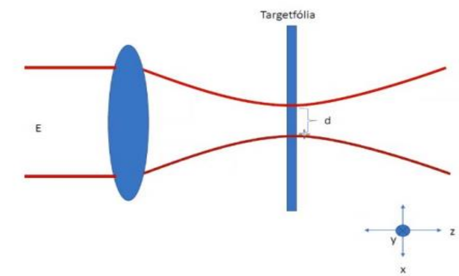


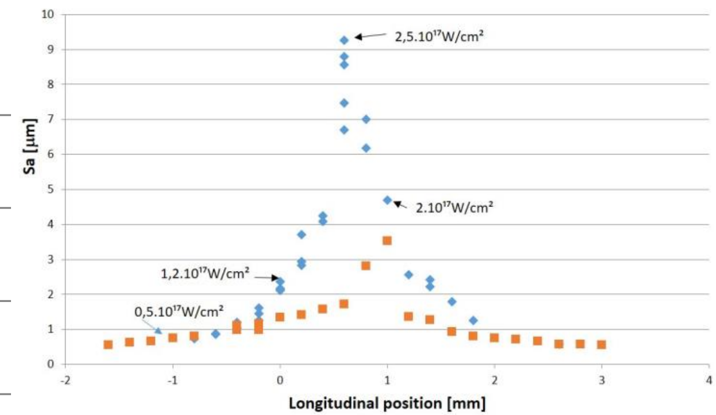
Laser pulse: 25mJ, 40fs

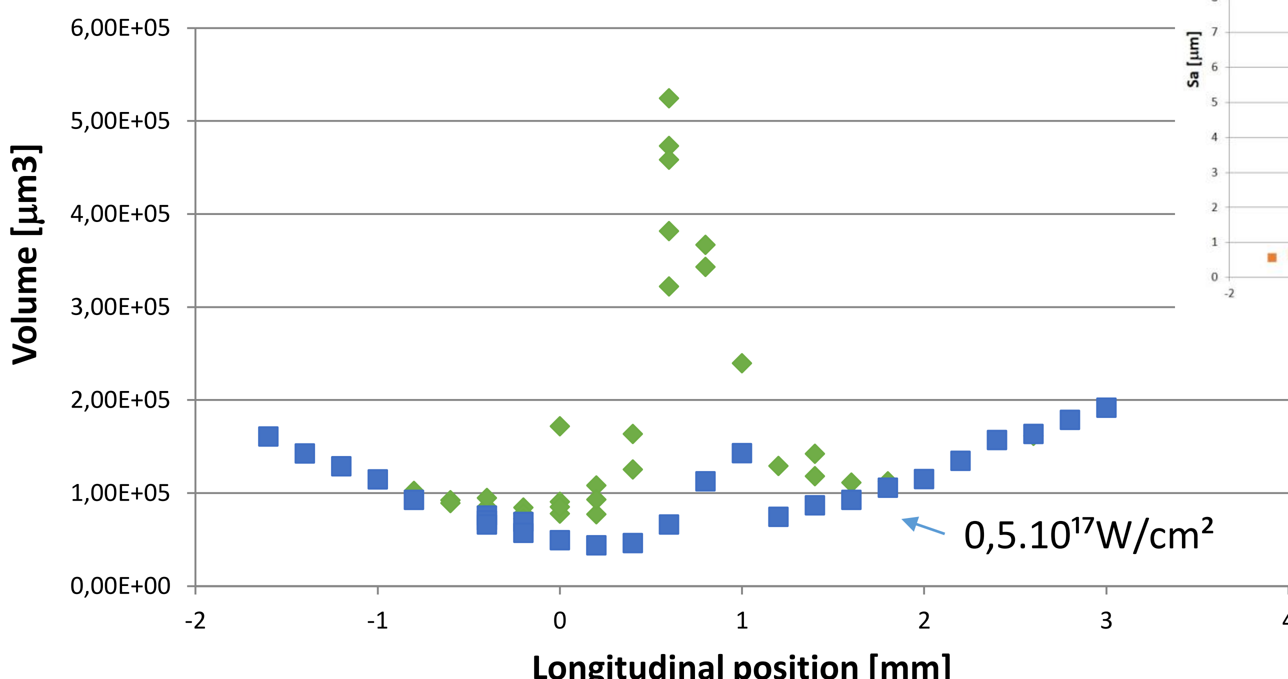
Au0	0.00 m/m%
Au1	0.12 m/m%
Au2	0.18 m/m%

CRATER VOLUMES





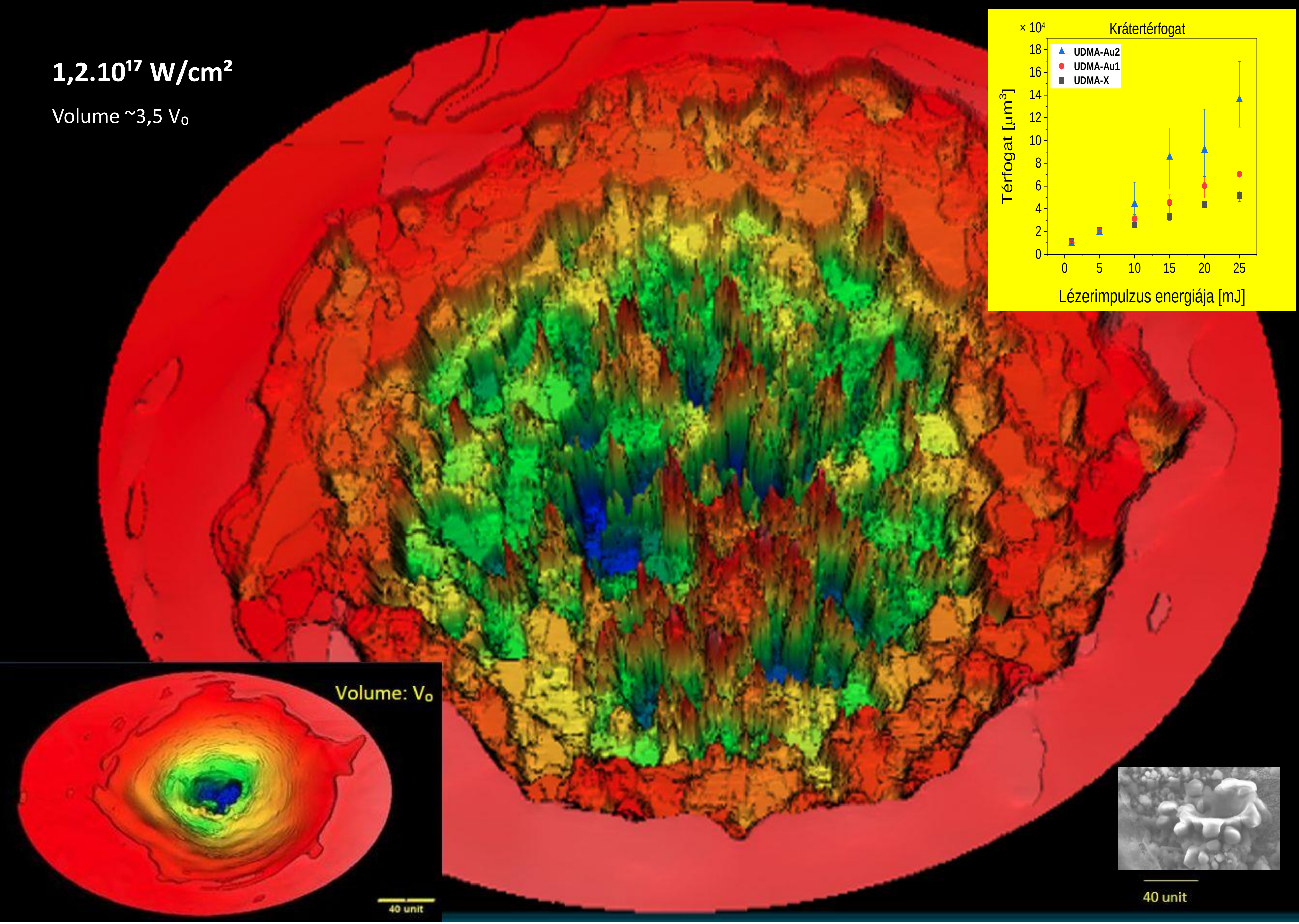


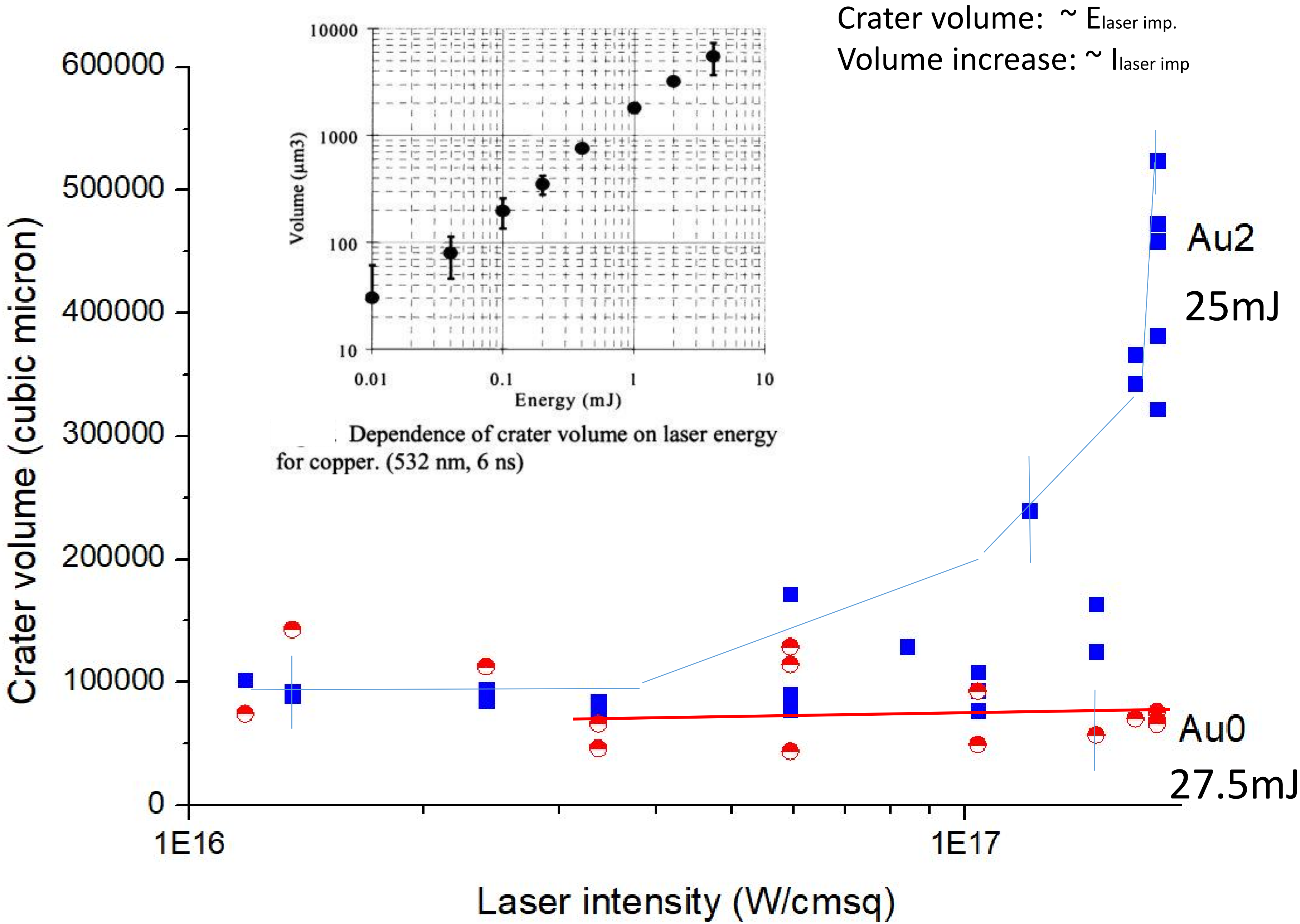


HIGH FIELD PLASMONICS WORKS!

$1{,}2.10^{17}$ W/cm²

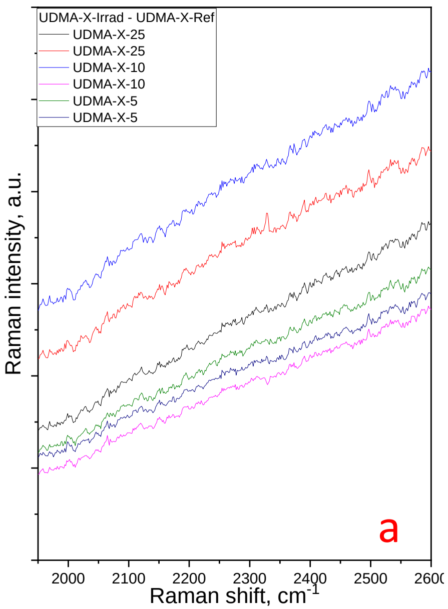
Volume ~3,5 V_0

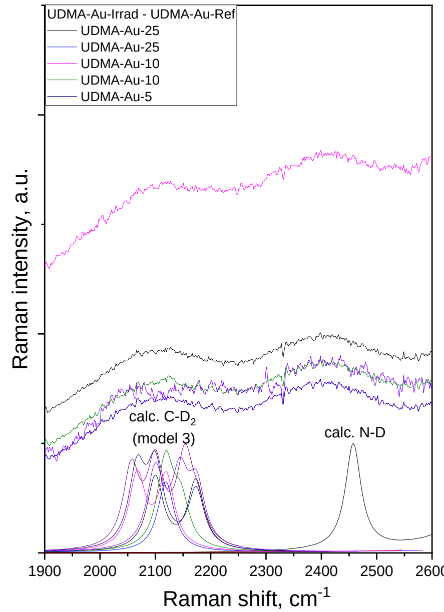


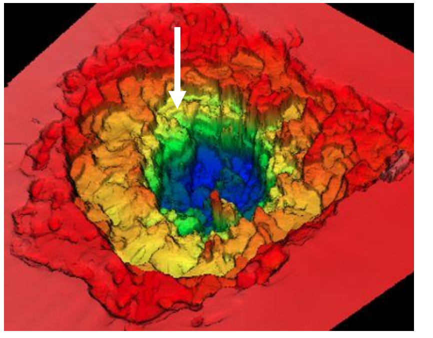

Crater volume: ~ E laser imp.
Volume increase: ~ I laser imp
600000
500000
400000
300000
200000
100000
0
Crater volume (cubic micron)
1E16
1E17
Laser intensity (W/cmsq)
Au2
25mJ
Au0
27.5mJ
10000
1000
100
10
Volume (µm3)
0.01
0.1
1
10
Energy (mJ)
Dependence of crater volume on laser energy for copper. (532 nm, 6 ns)

2.Diagnozis :Raman scattering from the crater surface

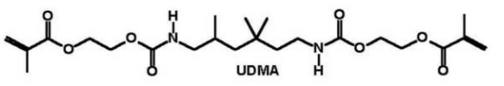
arXiv2210.00619(2022),submitted

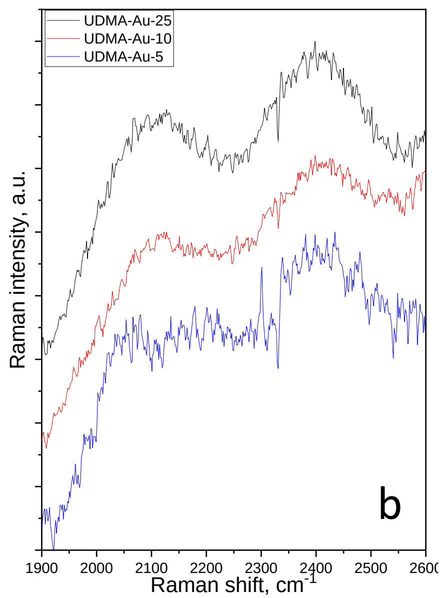


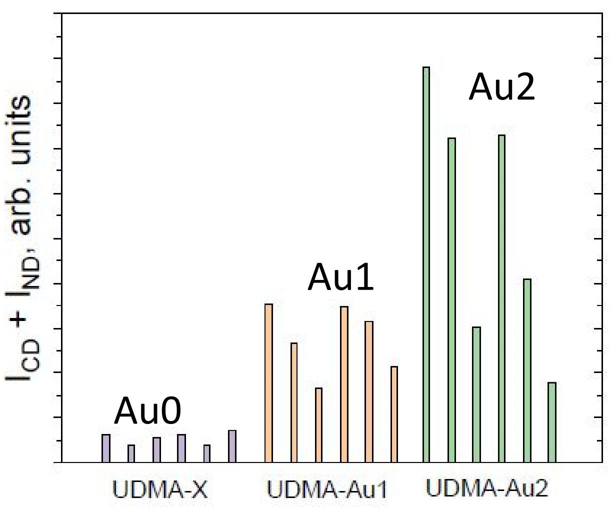


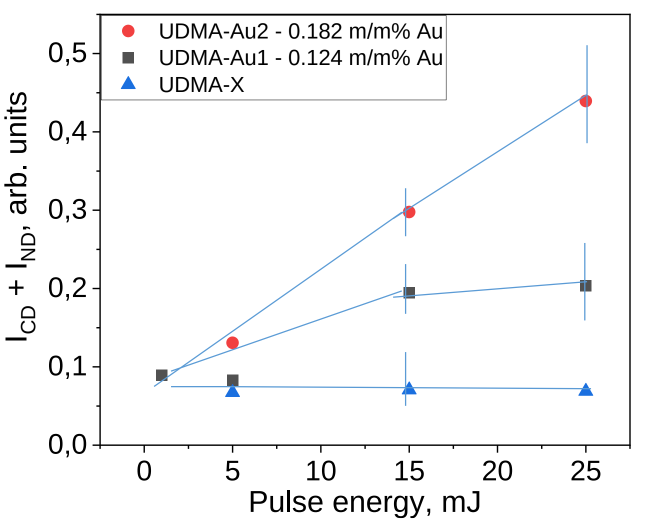


$I_{laser} > x.10^{16}$ W/cm²

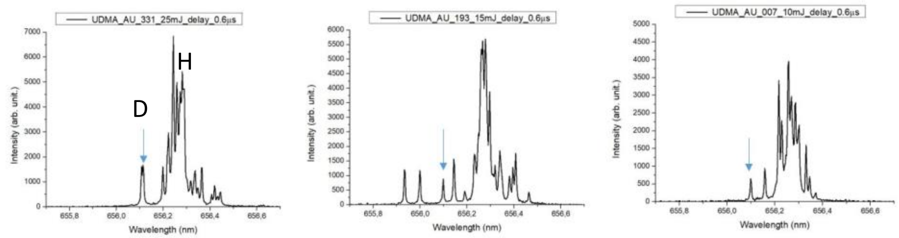








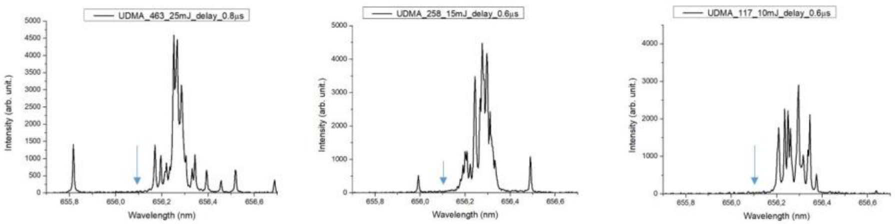
3.SOME RESULTS OF THE H^{α} AND D^{α} SPECTRAL LINES

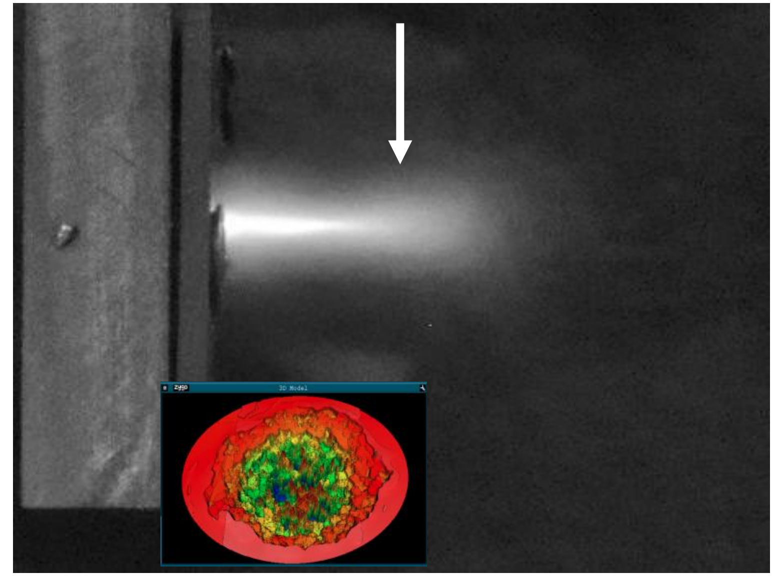


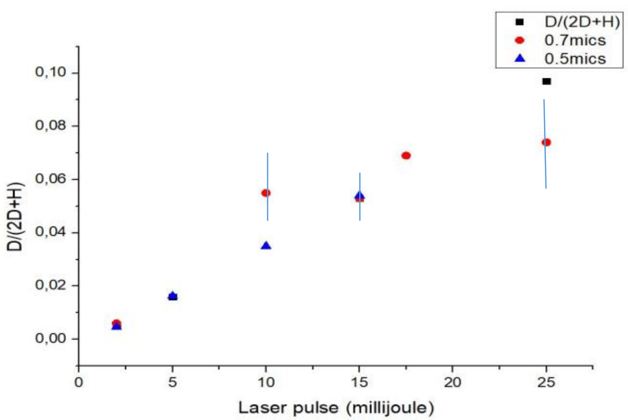
D/(2D+H): 10 +/- 0.9% | 4.5 +/- 0.3% | 4.2 +/- 0.4%

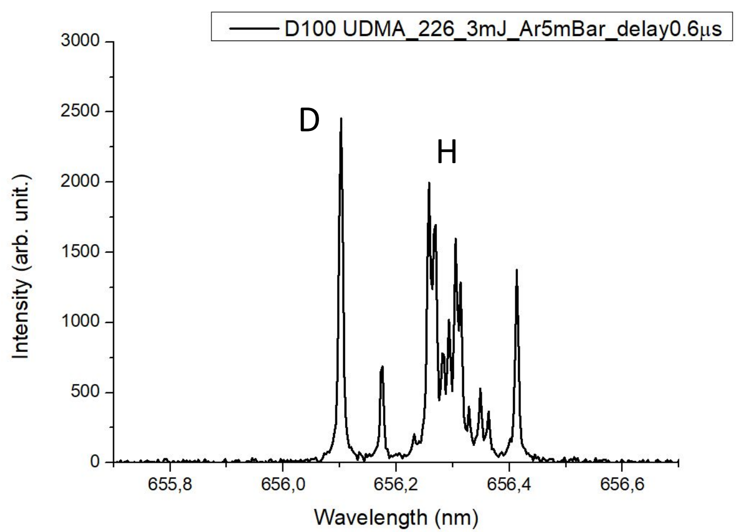
TYPICAL LIBS SPECTRA (at 3 laser pulse energies with and without Au nanoparticles)

No deuterium line

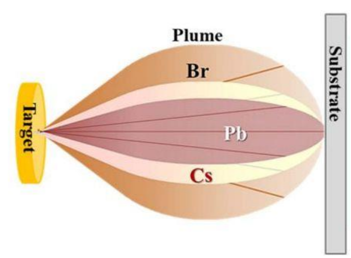








Deuterated (30%) sample



2D+H The total number of H atoms before the transmutation process

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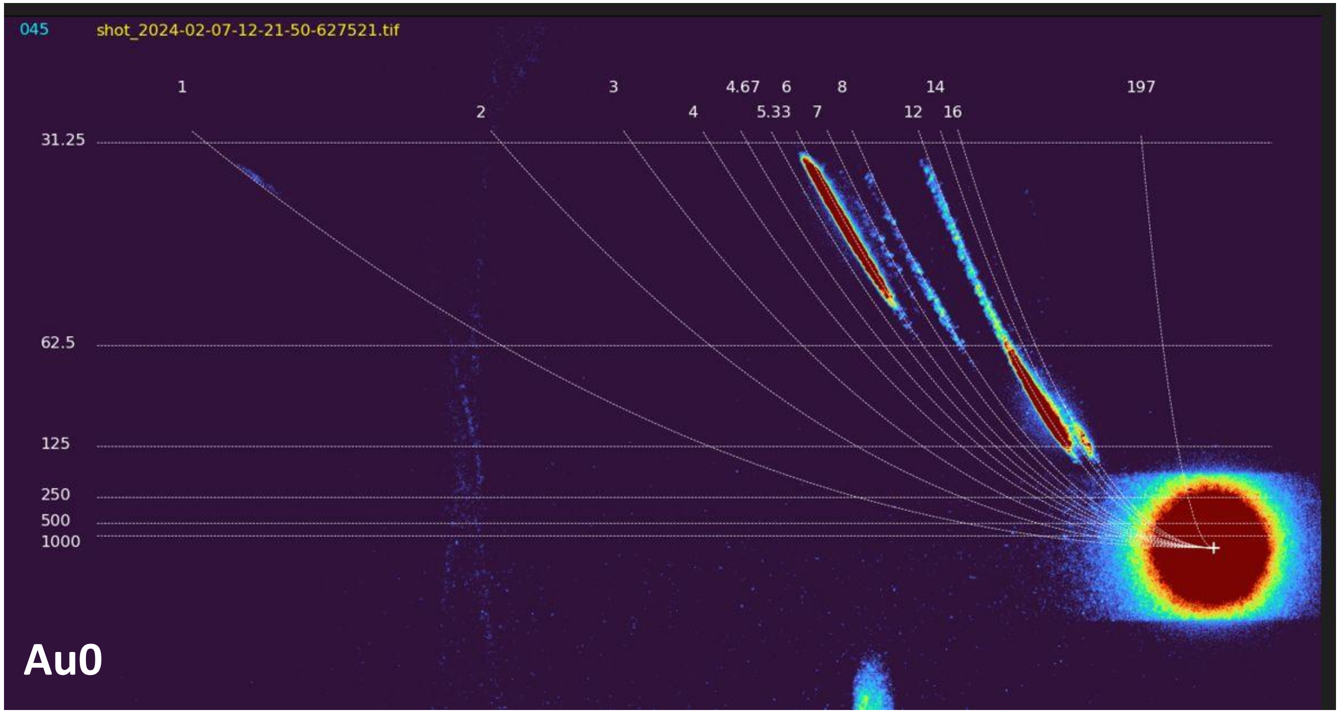
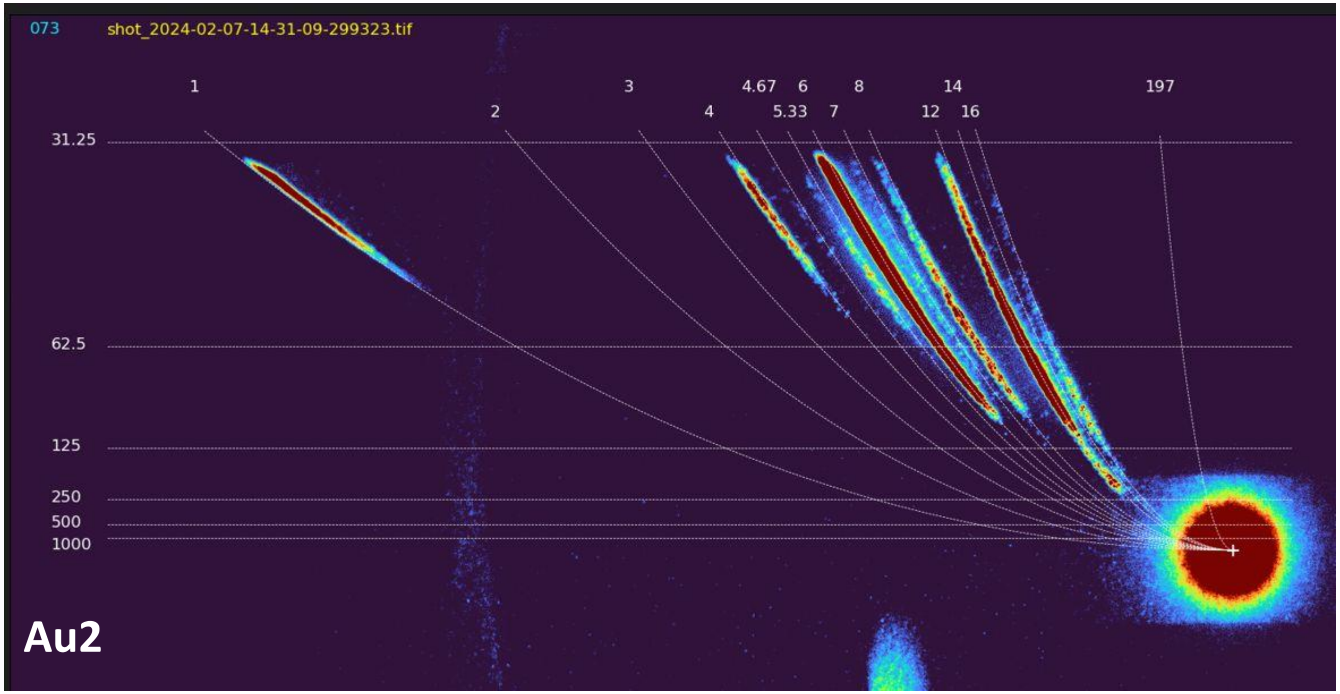
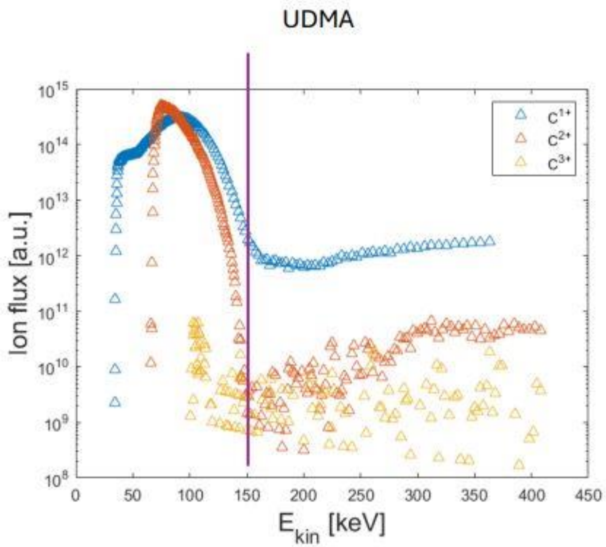
Number of D atoms in the case of 25mJ laser pulses : ~1.76×10^{15}

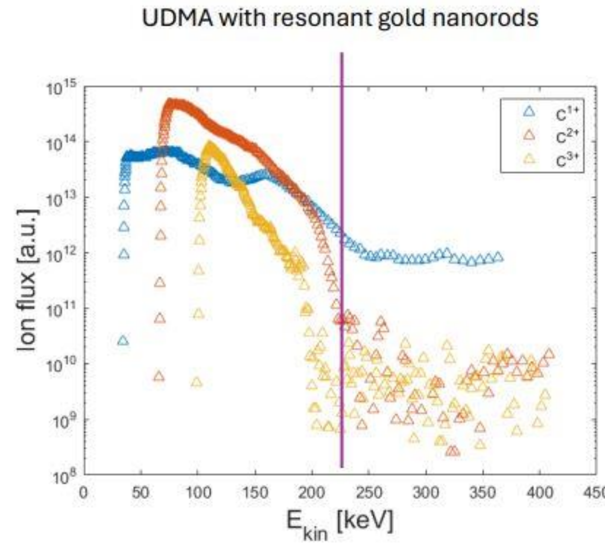
ELI-ALPS Szeged

Thompson parabola measurements





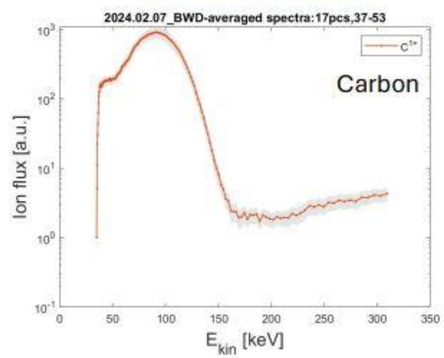


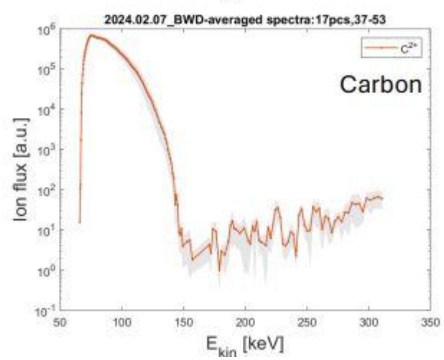


HIGH INTENSITY PLASMONICS WORKS

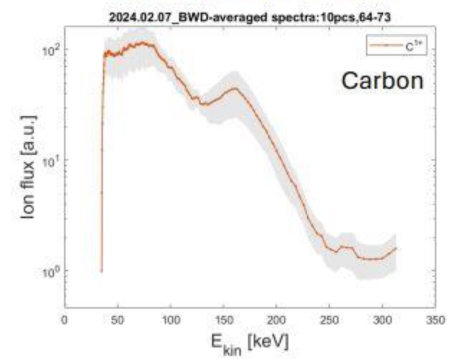
Cutoff energy

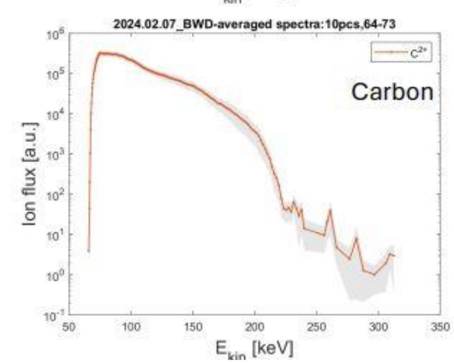
No resonant nanorods

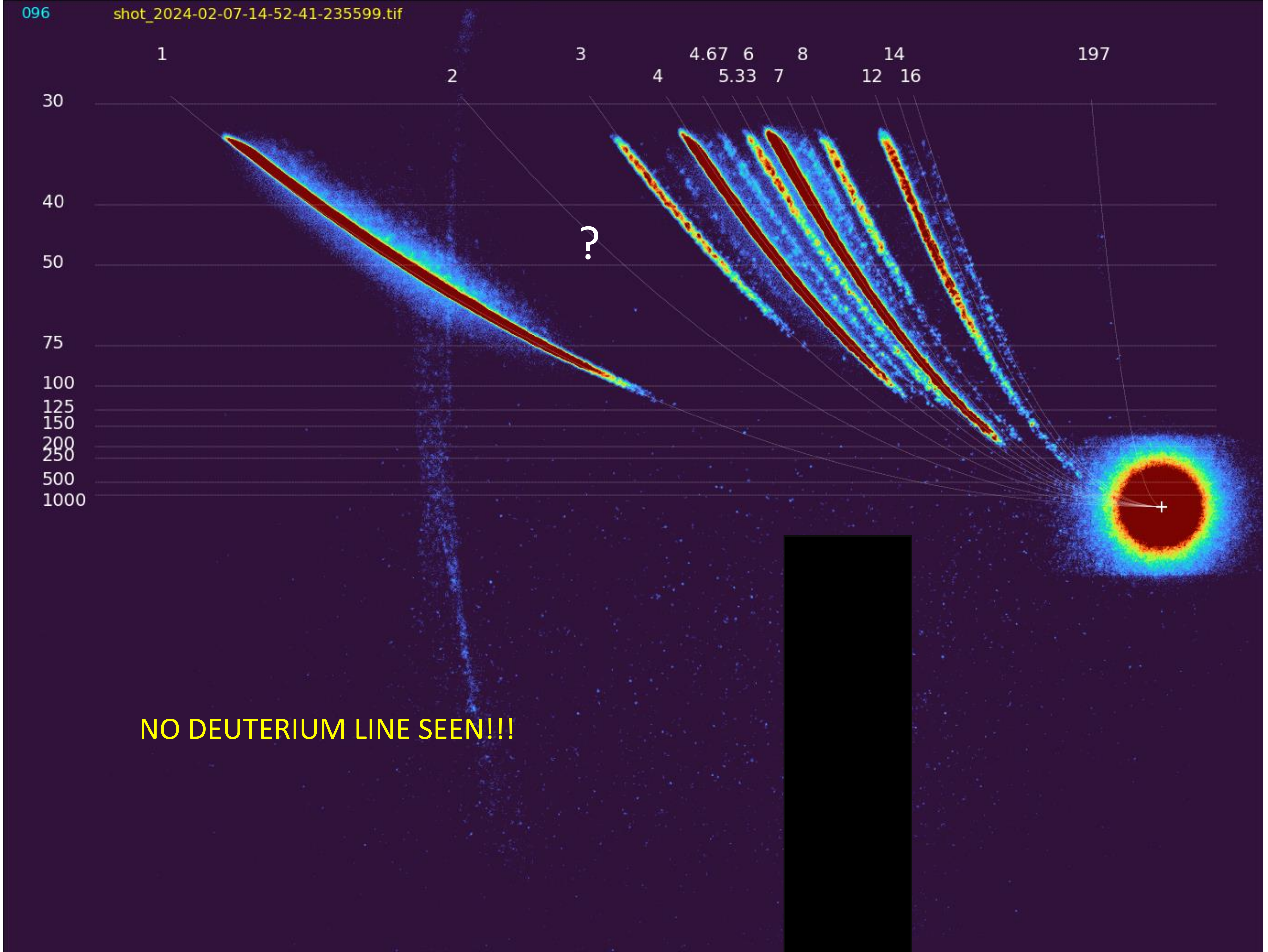




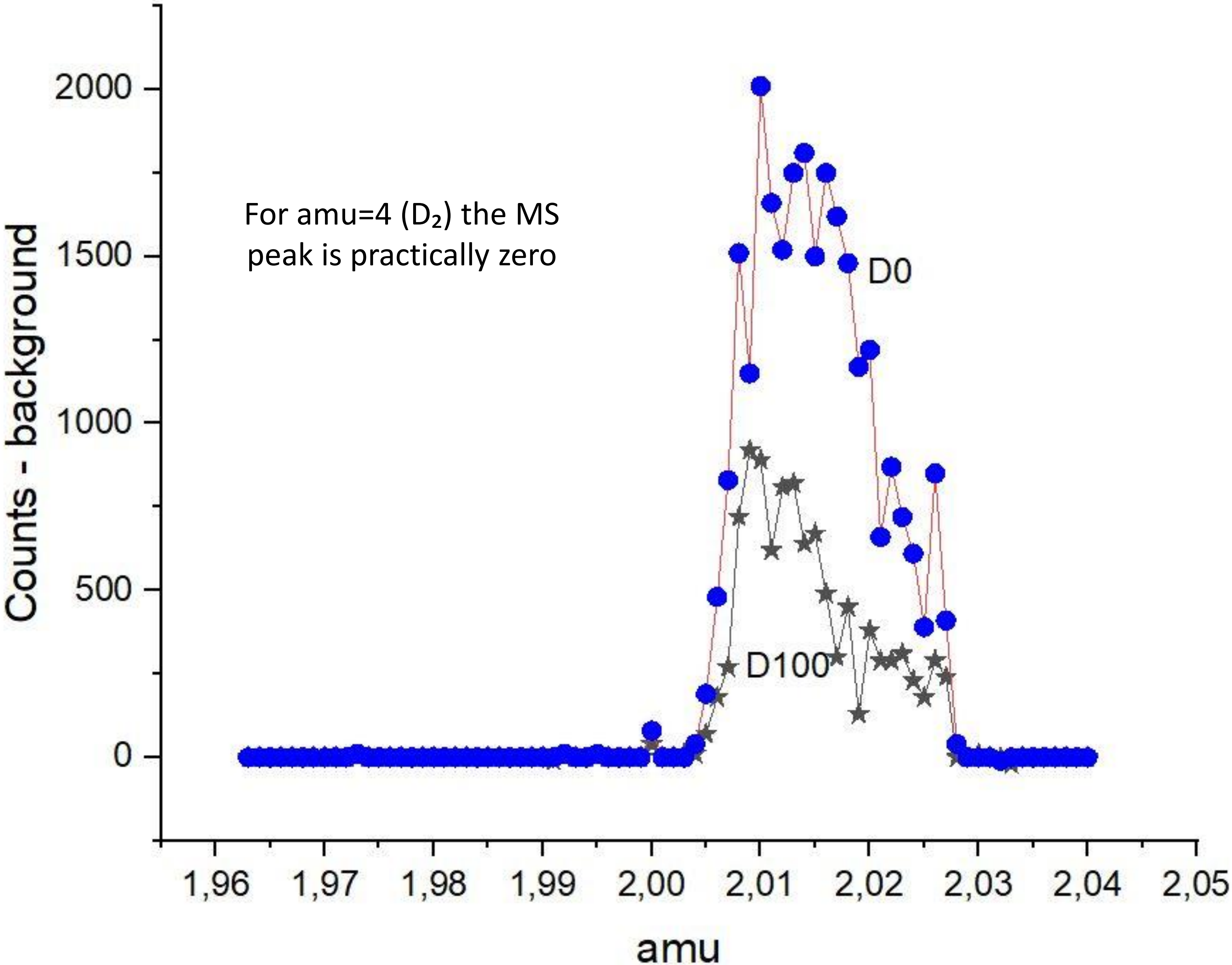
With resonant nanorods

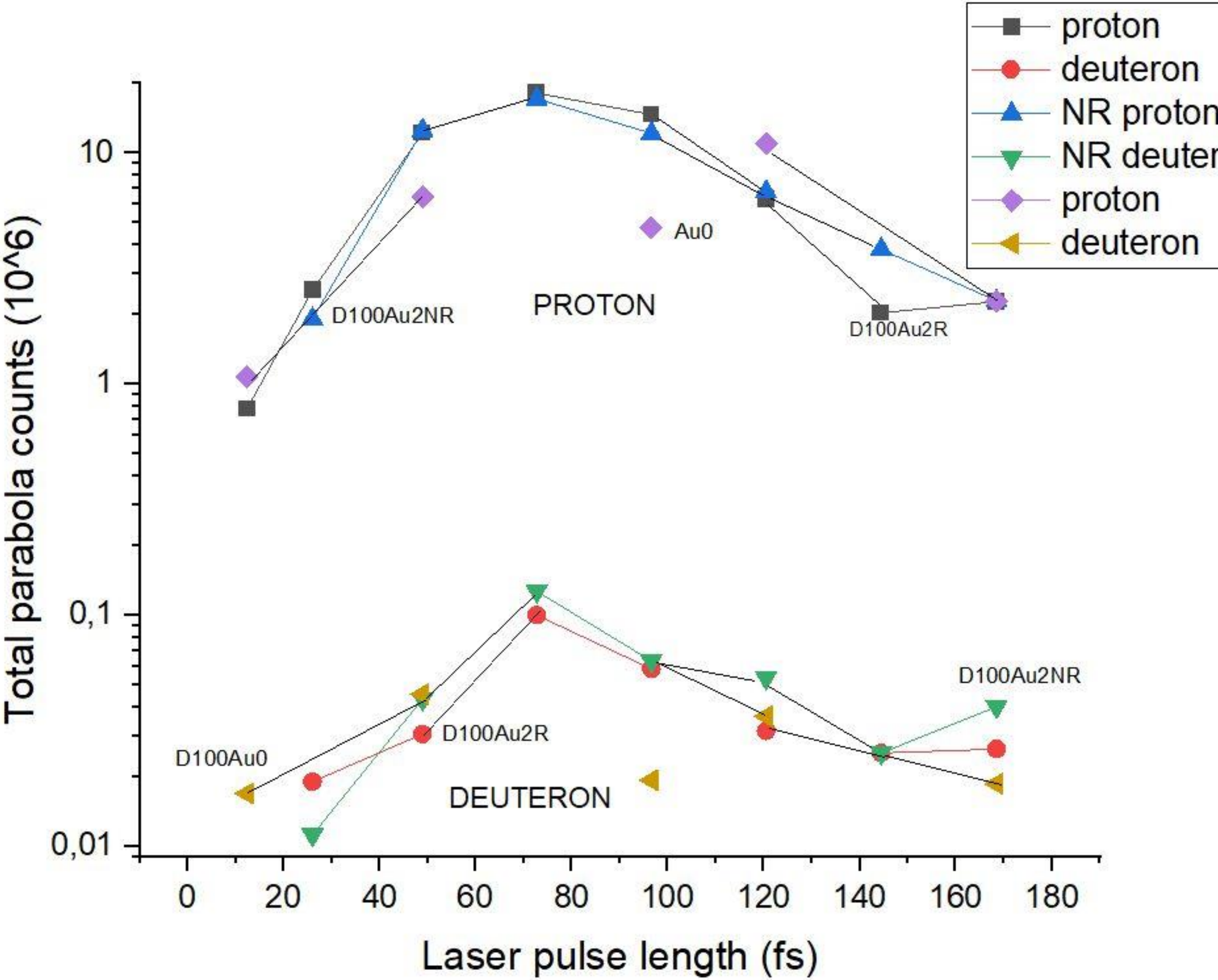




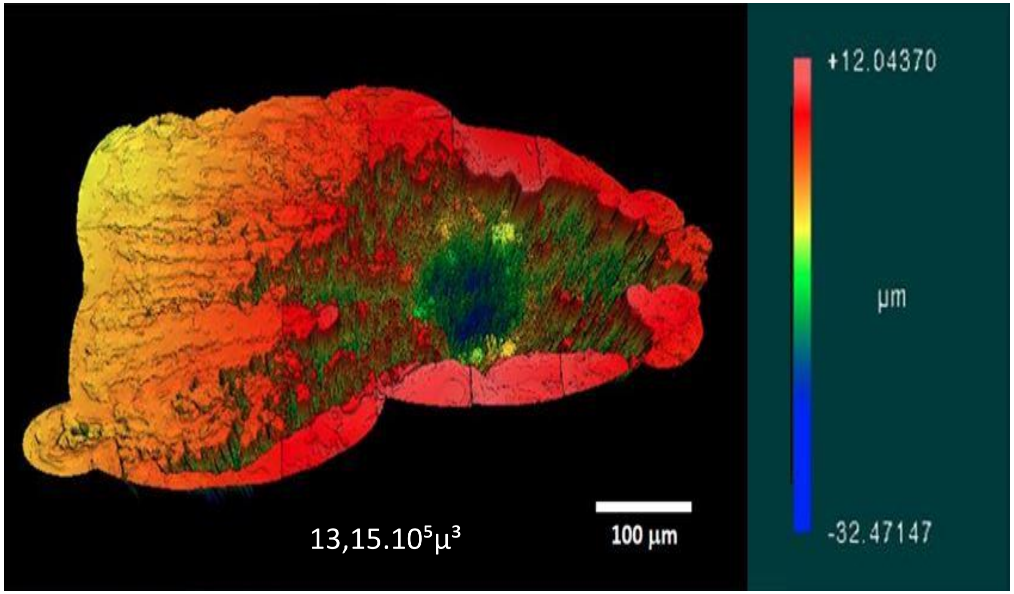


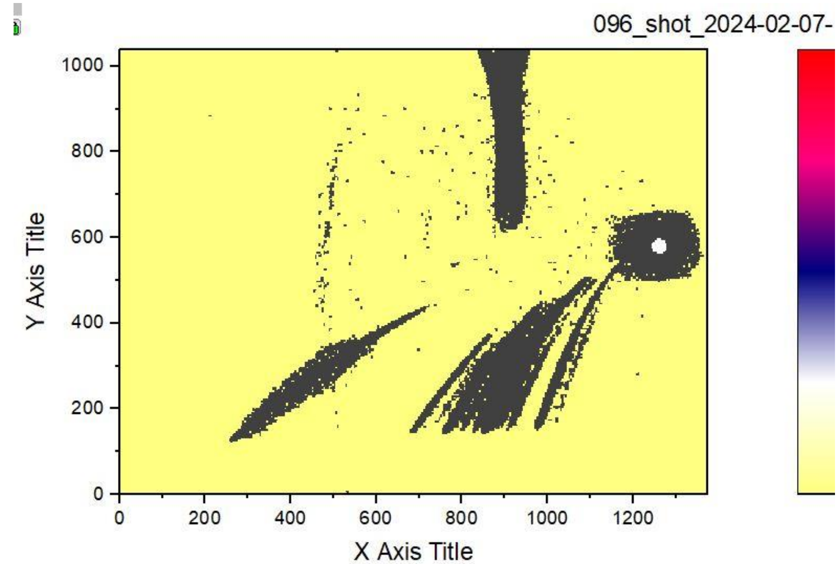
096
shot_2024-02-07-14-52-41-235599.tif
1
2
3
4
4.67
5.33
6
7
8
12
14
16
197
30
40
50
75
100
125
150
200
250
500
1000
?
NO DEUTERIUM LINE SEEN!!!


For amu=4 (D_2) the MS peak is practically zero
D0
D100
Counts - background
0
500
1000
1500
2000
1,96
1,97
1,98
1,99
2,00
2,01
2,02
2,03
2,04
2,05
amu



proton
deuteron
NR proton
NR deuter
proton
deuteron
Total parabola counts (10^6)
10
1
0,1
0,01
Au0
PROTON
D100Au2NR
D100Au2R
D100Au2NR
D100Au2R
D100Au0
DEUTERON
0
20
40
60
80
100
120
140
160
180
Laser pulse length (fs)

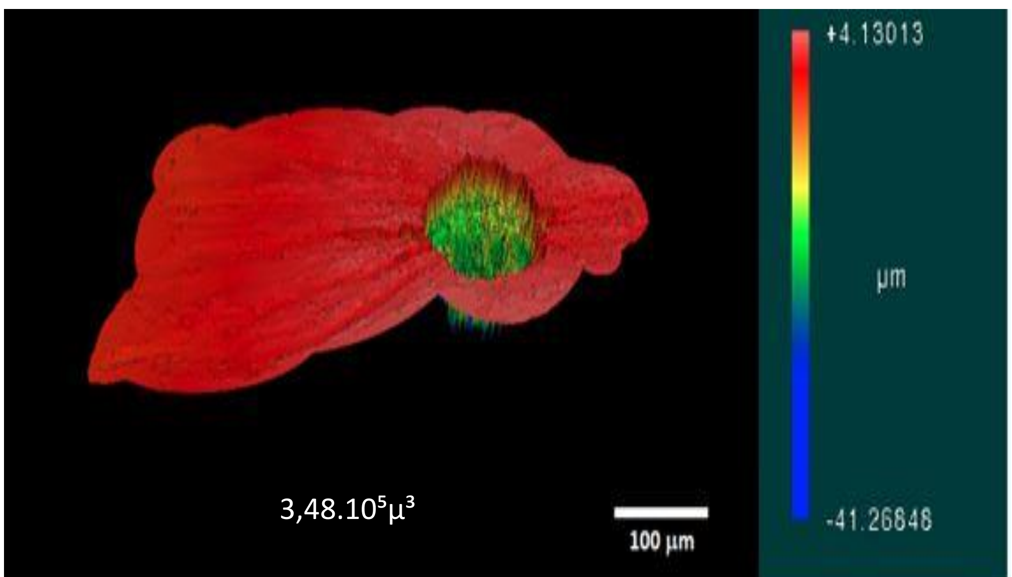


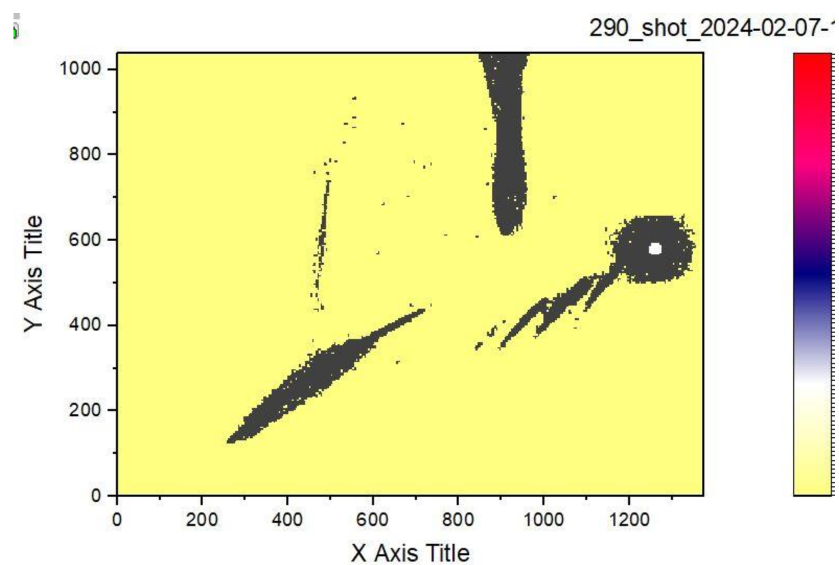


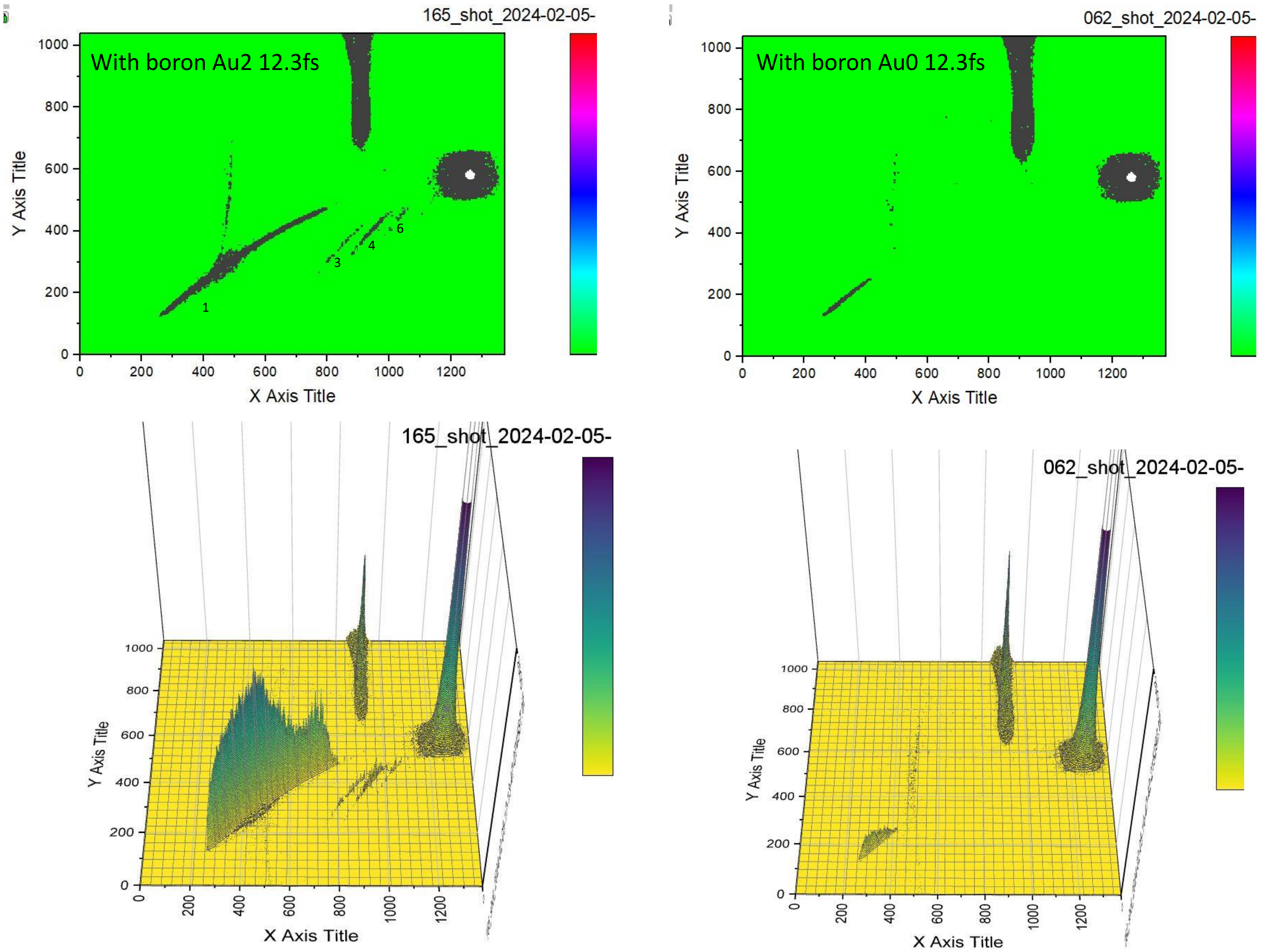
V_2/V_0 = 3.78

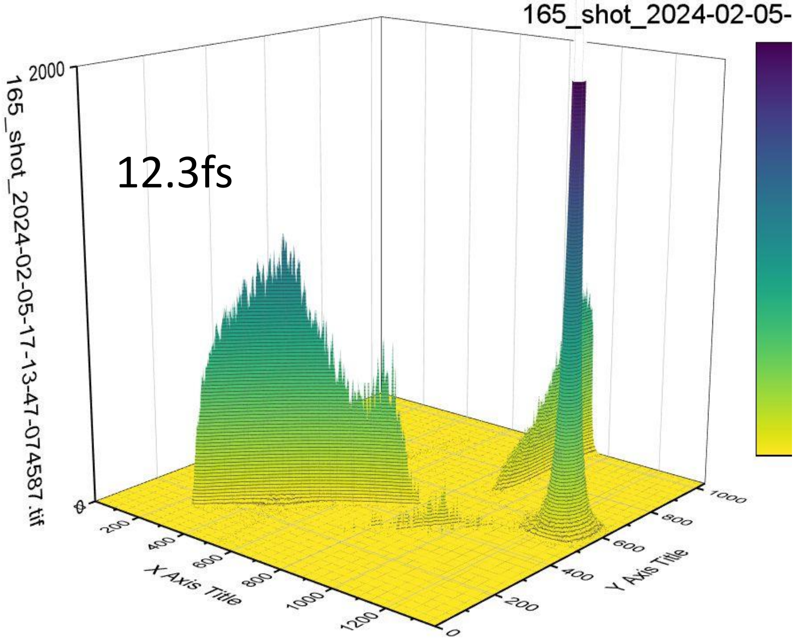
Laser pulse length: 43fs

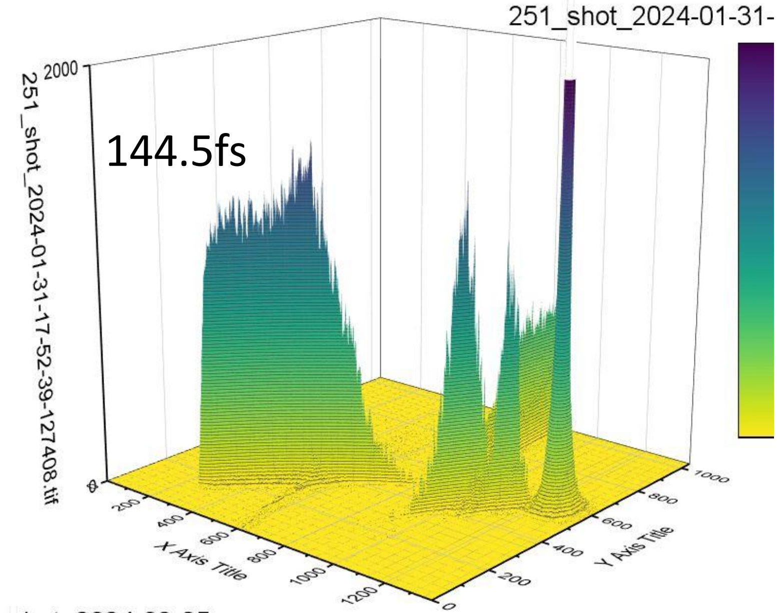
C_2/C_0 =6.54
Total: =~ 2

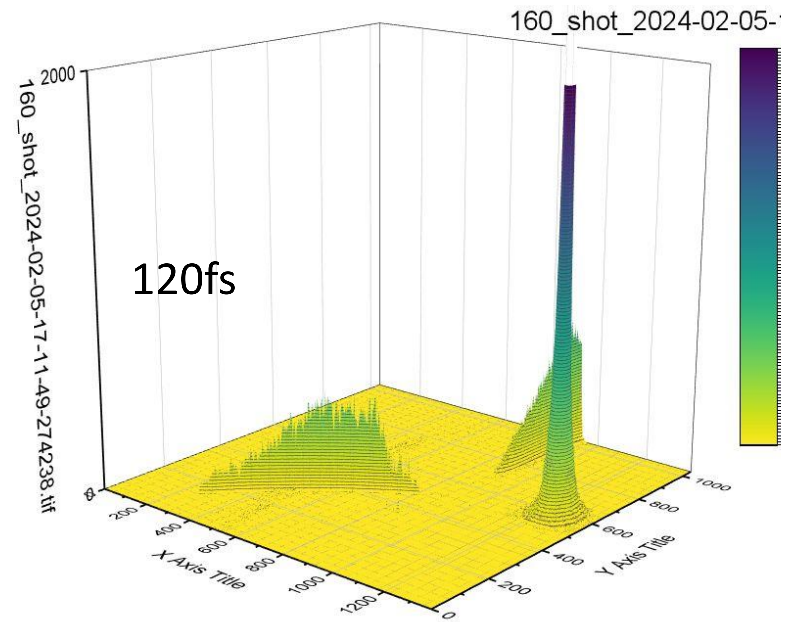


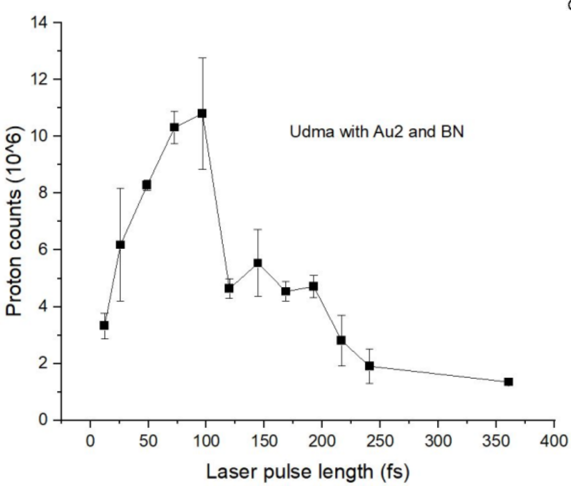



165_shot_2024-02-05-
With boron Au2 12.3fs
1
3
4
6
X Axis Title
Y Axis Title
062_shot_2024-02-05-
With boron Au0 12.3fs
X Axis Title
Y Axis Title
165_shot_2024-02-05-
X Axis Title
Y Axis Title
062_shot_2024-02-05-
X Axis Title
Y Axis Title

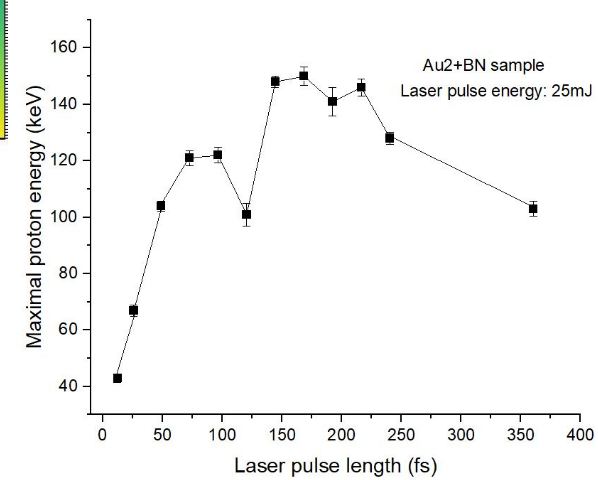


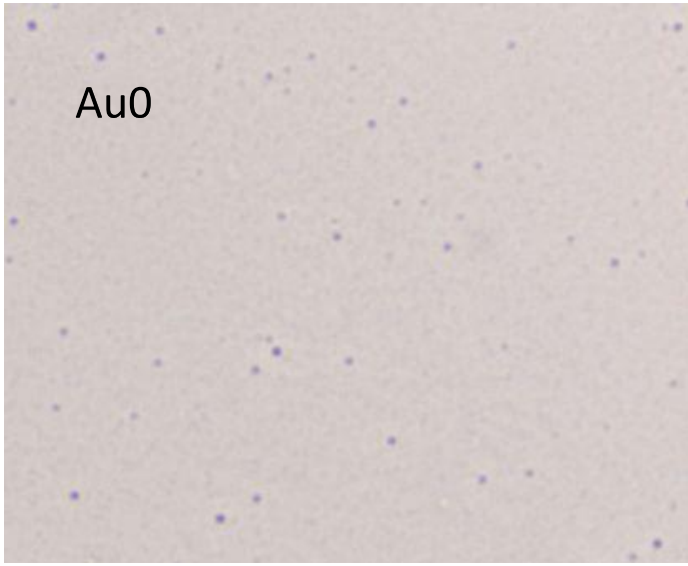


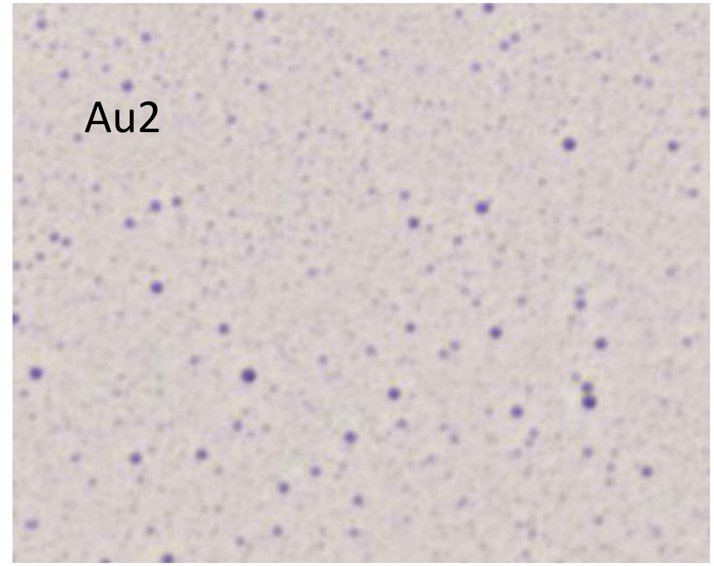


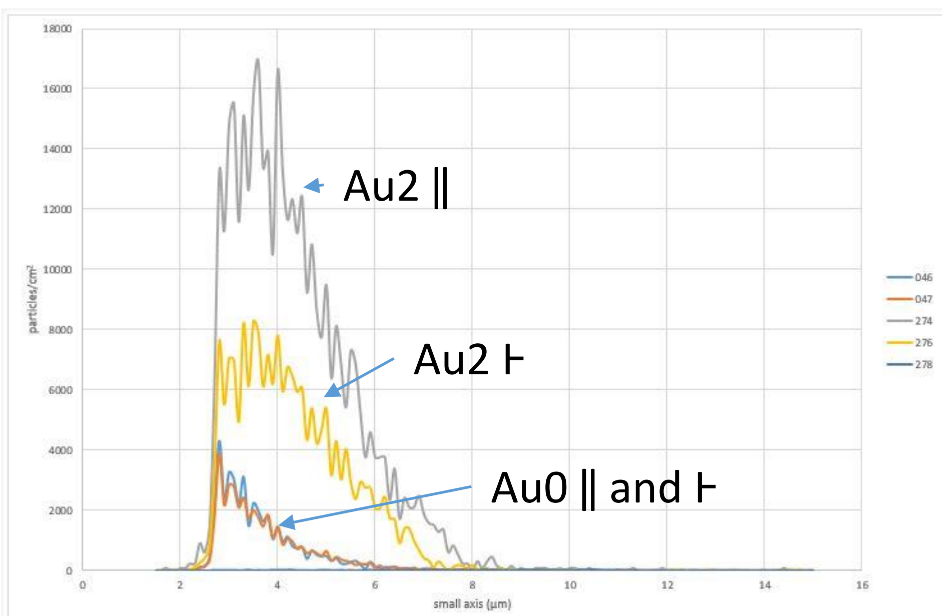


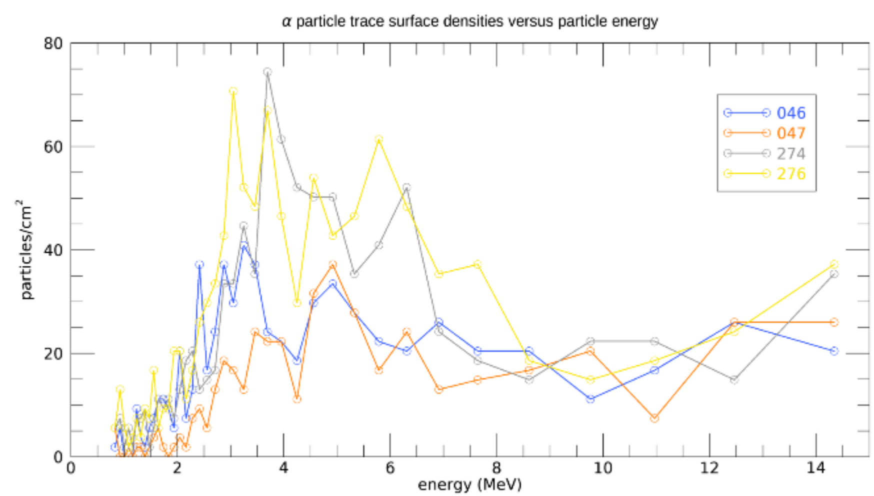
Samples with Au2 and BN

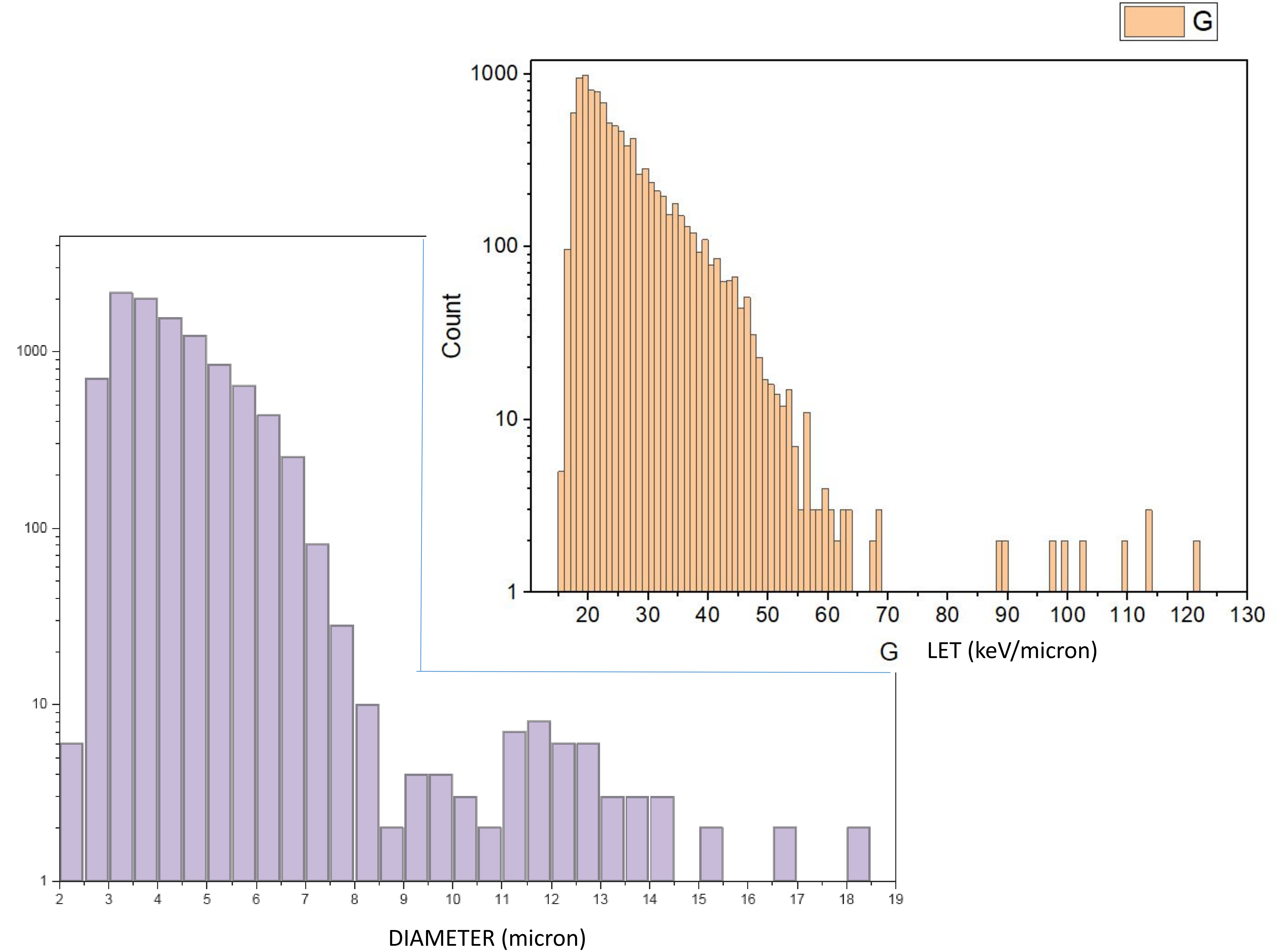



Au0


Au2


Au2 ||
Au2 ⊦
Au0 || and ⊦
particles/cm²
small axis (µm)
046
047
274
276
278


α particle trace surface densities versus particle energy
particles/cm²
energy (MeV)
046
047
274
276



G
1000
100
10
1
Count
20
30
40
50
60
70
80
90
100
110
120
130
G
LET (keV/micron)
1000
100
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
DIAMETER (micron)

CONCLUSIONS

1. Table-top lasers have been found to indicate the significant role of high field nanoplasmonics in potential nuclear fusion processes.
2. Above ~ 10^{17} W/cm² laser intensity the formation of the reflective plasma mirror is negligible, light penetrates into the sample.
3. Plasmonics works also at high laser intensities.
   - Significant energy production has been detected, indicated by the increase of the crater volume and higher particle energies in the Thompson parabola results (also in BN seeded samples).
   - The source of this excess energy could be partly the deuterium production, detected by 2 optical spectroscopy methods.
   - The particle energy of ions in the plume is always higher for samples with resonant plasmonic nanoparticles than for those without them.
   - The Thomson parabola spectrometer data indicate also this influence of the LSPP resonance effect on the basic processes.
4. Some preliminary results on nuclear processes have also been shown, but here further, more detailed studies are needed.
5. Several other studies are planned (nanoparticle size and material , direct nuclear detection of alfa particles, etc.)

THANKS FOR YOUR ATTENTION!

When the winds of changes are blowing some build shelters, but some others build wind turbines